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Contents

CHAOS-COMPLEXITY THEORY AND EDUCATION POLICY: LESSONS FROM MALAWI'S COMMUNITY DAY SECONDARY SCHOOLS

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Abstract. Since the democratic dispensation of 1994, the education sector seems to be in perpetual transition with numerous facets of policies being introduced against a background of alleged poor management, understaffing and a poorly paid cadre of teachers. The situation was at one time likened "to a patient on a resuscitation bed in a hospital". Despite this seemingly chaotic and complex scenario, the education system has managed to survive. Using the Malawi Community Day Secondary Schools (CDSS) policy, the paper intends to draw some insights from public policy's Chaos and Complexity theory to explain why the education sector still manages to survive and show resilience (on the "edge of chaos") despite the apparent overwhelming challenges.

Keywords: education policy; Malawi; Community Day Secondary Schools (CDSS); chaos-complexity theory; participation

1. Introduction

The Ministry of Education, Science and Technology is one of the largest in Malawi and over the years it has been experiencing numerous challenges that have largely been analyzed in the academic literature (Kayuni & Tambulasi, 2007; Rose, 2003a, 2003b).[1,2)] In order to among other things, enhance participation and improve secondary school access, Community Day Secondary Schools (CDSS) were established in 1998. However, this move led to a "crisis" in the secondary school education especially in the areas of quality and relevance of the education being provided. The available literature limits the discussion over the issue to micro policy implications; hence it does not extend this analysis to the wider system policy theory domain. The paper introduces the chaos-complex policy theory in order to contextualize this CDSS policy decision. Chaos theory argues that in most complex systems, despite a seemingly chaotic and confusing scenario, there are patterns of order which are achieved in the zone of what is referred to as "edge of chaos"- this is where they best deliver. In this case, from a casual observation, public policies applied to complex systems may be deemed to have failed when in reality there is a self-regulation scheme in operation that ultimately assists the system to deliver. On the whole, the paper argues and demonstrates that the Malawi education policies have to a larger extent driven the education system to the "edges of chaos" where it is arguably "thriving".

In order to enhance clarity of the paper and provide a proper setting, the paper starts by analyzing the concept of chaos-complexity theory and this is followed by a discussion on the global context of education policy and reform as well as policy making in democratic Malawi. The third section analyzes the education policy in Malawi after 1994 and establishment of Community Day Secondary Schools followed by a critical analysis of the policy crisis/chaos within the Community Day Secondary School sector. Before concluding, the last section provides the underlying order within this crisis.

2. Chaos-complexity theory

Although the chaos-complexity phase in policy analysis can be traced back to some years before mid 1990's, its impact has largely been recognized in the 2000's. Taking into consideration the multiplicity of policy actors, it became clear to most policy analysts that the policy environment is more complex, unpredictable and confusing akin to chaos. However, the chaos-complexity theory gives an "appreciation, not distrust of chaos and of uncertainty, stressful times" and it further stresses that "real change and new structures are found in the very chaos they [managers or policy makers] try to prevent" (Overman, 1996).

In order to fully appreciate the relevance of chaos-complexity theory a brief analysis of the development of the concept as well as its relation to systems theory, and finally, unpredictability and crisis is discussed below.

2.1 Development of the concept

The name "chaos theory" comes from the fact that the systems described are apparently disordered, but it goes further by finding the underlying order in apparently random scenarios through its extension to analysis of complexity theory. The first person to realistically experiment in chaos was a meteorologist Edward Lorenz. While working on the problem of weather prediction in 1960, he discovered that the data produced by his computer, despite its seemingly chaotic nature, showed some patterns that could meaningfully explain certain developments. Through analysis of this data, it was revealed that a small change in the weather (which could initially be regarded as negligible) in one city can exponential have devastating effect in another far way city (Kershaw & Safford, 1998). This was popularly known as the "butterfly effect" or "sensitive dependence". In this case, a small change in the initial conditions can drastically change the long-term behavior

of the system. Therefore, "chaos is a system theory that attempts to understand the behavior of nonlinear, unpredictable systems" (Bechtold, 1997). Originally, the concept was successfully applied in the natural sciences such as chemistry, biology and physics so as to enhance understanding of certain emerging trends in those fields. Over the years it was also noted that most social science disciplines tend to be confronted with characteristics of non-linear and unpredictable phenomenon. Consequently "this recognition has led to a surge of interest in applying chaos theory to a number of fields" (Levy, 1994) and these include international relations, economics, management, education and policy analysis.

2.2. Chaos and policy systems theory

Chaos theory is not completely new in policy analysis. Policy systems theory, which is one of the core perspectives in policy analysis, forms the basis of chaos theory. As Overman (1996) observes "chaos theory has its roots in simple systems theory and owes much to this now-familiar approach"; however, chaos theory has been developed further by generating its own perspectives to the understanding of policy processes. In general, a system is a set of parts that interact with each other and function as a unified whole. Policy systems approach argues that government or decision makers receive in puts inform of demands or support from the social, economic and political environment which they process and make decisions or policy actions which are referred to as outputs. This output may also ultimately be regarded as input through the feedback process. Policy systems approach argues that it is the goal of the system to achieve and maintain the state of equilibrium so as to ensure policy stability and progress, i.e. the inputs should balance with the output. Chaos theory, however, argues that policy stability is rarely achieved and should not necessarily be the goal of a policy system. More often than not,

policy systems are in a state of disequilibrium which leads to a seemingly chaotic situation. In this way, chaos theory is an *evolutionary* system theory.

The link between chaos and complexity is a little bit tricky as it dwells much on an abstract academic construct. This is complicated by the fact that "the literature on complexity science gives little detail to understanding "complexity" itself (Medd, 2004). This is even clear when it is noted that there is "difficulty of giving definitions and measurements of complexity" (Medd, 2004). Consequently the link between chaos and complexity has always been problematic. However, Luhmann (in Medd, 2004) argues that "we live in a world in which it is not possible to connect the totality of anything". The link with complexity comes about because chaos "sees a system as continuously transforming itself to a higher level of complexity, making changes that are irreversible"; in this case, "though a dynamic system may appear to be chaotic, its identity, history, and sense of purpose (strange attractor) define its boundaries and guide its evolution and growth" (Bechtold, 1997). As Cohen & Stewart (1994) suggest "one of the great surprises of chaos theory is the discovery of totally new simplicities, deep universal patterns concealed within the erratic behaviour of chaotic dynamical systems." Specifically, complexity is ultimately achieved when a dynamic system which is self-organizing (in how it orders and structures itself) grow and change.

The assumed progression in chaos-complexity theory is that a policy system starts at an optimistic level of high predictability and "as the predictability horizon is approached, however, small uncertainties will begin to creep into the system which will tend to bend or distort the rules on which we base our predictions"; ultimately "the uncertainties will be self accelerating and lead, inevitably, to a point of rapid transition into chaos" (Bechtold, 1997). The edge of chaos is somewhere between order and disorder or between a chaotic and complex situation (Cloete, 2004). According to chaos-complexity theory, this is the best scenario for an organisation or policy system because

there is a higher degree of "creativity and innovativeness" (Praught, 2004) hence the term "thriving on the edges of chaos". Bechtold (1997) aptly describes this situation by arguing that

> [A] system betters itself, creates its own future, and continuously adapts to its environment based on its intelligence and information. For this, it needs to tap not only its more stable parts but also those at the "edge of chaos" that are chaotic or even dissipative. Through the freedom of operating with an open flow of information from its "edge," it stays connected to its simultaneously evolving environment and enhances its ability to handle environmental changes.

Table 1 summarizes the key components of the traditional, chaotic and complex policy situations as already discussed above.

Table 1. Differences amongst the traditional, chaotic and complex policy situations

Traditional policy system and rational approach	**Chaotic policy situation**	**Complex policy situation**
Control	Chaos	Complex
Order	Disorder	Order within chaos
Objective	Subjective	Interconnected
Safe	Unsafe	Dynamic
Certain	Uncertain	Adaptive
Predictable	Unpredictable	Pattern
One best way	Any way	Multiple approach
Structured	Unstructured	Codetermined
Equilibrium or homeostasis	Disequilibrium	Dissipative Structures
Holism: the whole is equal to the sum of the parts	Irreducibility	Inexplicable by the parts
Feedback	Irreversibility	Self-regulating

Adapted from Darwin (2004); Overman (1996) and Cloete (2004)

2.3 Unpredictability and crisis: the core processes in chaos-complexity

In relation to policy changes, Parsons (1995) argues "the student of public policy faces a complex and contradictory body of analysis". Grindle & Thomas (1991) add that "all policy choices thus involve uncertainty and risk". This uncertainty and risk is heightened by the fact public policy analysis is shrouded in what Nagel & Treaser (2004) call three methodological problems. These three methodological problems are: (a) complexity which leads to problems associated with multiple conflicting criteria and conditions of multidimensional measurement; (b) uncertainty of the consequences of current decisions; (c) effectuality or how to ably communicate in a persuasive manner hence convince public policy makers. Based on the three observations by Nagel & Treaser, uncertainty is probably the commonest problem that policy makers and analysts are confronted with. Taking into consideration the assertion by chaos-complex theory that even a small change in the policy "can have big effects that will result in unexpected outcomes as complex systems change overtime" the manifestation of a crisis can not be underestimated. Referring to change in the American policymaking, True et al. (1999) initially claim that "stasis, rather than crisis, typically characterizes most policy areas", but they later admit that "however, crises often occur". Embedded in this crisis is chaos. In the context of post-secondary education system in USA and Canada, Kershaw & Safford (1998) state that "chaos appears to reign" and this state will "best be understood with reference to chaos theory".

Crisis forms a critical element in policy process and according to chaos theory, crisis ushers an institution or the policy issue to be rightly placed: on the edges of chaos. Grindle & Thomas (1991) argue that "if elites perceive a crisis…the issue will command the attention of senior policy makers" and in this case "their decisions are likely to be more radical or innovative than when a crisis does not exist, and action will often come quite

quickly". On the other hand they add that "if there is no perception of crisis, the stakes for government are lower". In relation to the education sector, this is why "the science of chaos tells us that signs of disorder might well be signs that the system of education is healthy and on its way to a much improved new order" (Sullivan, 1999).

3. Global context of education policy and reform: role of the World Bank

One of the major roles of research is that it helps guide the formulation as well as revision of any particular policy. In developing countries, there are several limiting factor to extensive research. Due to scarcity of expertise and lack of government funding, education research in developing countries is in most cases initiated and financed as well as conducted by international donor agencies- the World Bank is the leading agency in that respect (Boyd, 1999). According to Boyd (1999), the World Bank's education policy research findings have a profound "intellectual and political influence" in the developing countries. As correctly observed by King (1991), "one reason for the widespread knowledge of the research findings of the Bank is that their reports are relatively easily available at little or no cost" and in addition to this, "they constitute the state of the art". Probably of greater significance is the fact that the Bank's research reports "fill a major gap" in scarcity of educational literature "that looks across a region or continent" especially in Third World countries (King 1991).

Other influential agencies that have an influence on education policy are the United States Agency for International Development, the British Overseas Development Agency now called DFID, various UN agencies (such as the International Labour Organization, UNESCO) as well as donor countries such as Canada and Sweden (King 1991). Due to the enhanced relationship amongst the donors, the World Bank is seen as a coordinator and plays a lead-

ing role in influencing the development of educational policy (Lauglo 1996, p. 221). Above all, other donor agencies often tend to rely on the research findings of the World Bank to develop their own funding criteria (Lauglo 1996). The process of developing education policies can be said to follow three stages which are theoretical development, experimentation and finally generalisation (Ruperez, 2003). To a larger extent, the World Bank in developing countries seems to have powerful control of the theoretical development of educational policy. It is often seen in terms of "international expert." Consequently, "on some debates about education, the signals broadcast from the agency (i.e., World Bank) perspective are so powerful, it is difficult to hear the local voices at all" (King, 1991).

The notion of community participation had been advocated by the World Bank back in 1986 (Mundy, 2002). The World Bank in 1986 developed an "in-house policy note" titled *Financing Education in Developing Countries* in which three main issues were highlighted for educational reform prescription (Mundy, 2002): (1) recover the costs of higher education through user fees and reallocate these resources to the primary level; (2) develop a credit market in higher education; (3) decentralize the management of schools and *encourage private and community schools* in order to increase competition and generate a demand-side push for better quality and efficiency (emphasis my own).

Significantly, despite Mundy's (2002) remarks, these three issues have recurred (either directly or indirectly) in several other World Bank policy papers.

Apart from the World Bank, most other international organisations also encourage community participation in education. For instance, UNESCO's 1996 report, *Learning: The Treasure Within*[3)] report emphasizes that the success of educational reforms mainly depend on local communities (including parents, school heads and teachers). The report adds that top-down

approaches have failed to bring about positive change in education hence calls for decentralisation in the education system.

However, the World Bank's policies in education have been the subject of criticism from several quarters. It is not surprising therefore that "the views of the Bank on many matters in the education sector, and on Third World economies more generally, are highly controversial" (King, 1991).

4. Policy making in democratic Malawi

Malawi's policy making process during the one-party era was highly centralized with the executive and the Malawi Congress Party (MCP) conventions taking a leading role in setting the agenda for policy formulation. Multiparty politics embraced in 1994 witnessed an opening for multiple players in the policy formulation process such as the media, NGOs, political parties etc. Although formally the Office of the President and Cabinet (OPC) has mandate to coordinate policy formulation in the country, Chinsinga (2007) observes that it is still very difficult to fully determine the specific institutional framework for policy formulation in the country. Chinsinga (2007) identifies the main actors in policy formulation as mainly being composed of the executive, the government bureaucracy, and international donors- in this case the donors are the most influential because Malawi is mainly donor dependent. An important observation made by Chinsinga (2007) is that the policy making process in Malawi is complex and tends not to follow the policymaking cycle model which is depicted in policy literature.

5. Education policy in Malawi after 1994 and establishment of Community Day Secondary School

In terms of policy, the notion of community participation in education is well entrenched through the *Malawi Vision 20:20*, *Poverty Reduction Strategy Paper* (PRSP) and the *Education Policy Investment Framework* (PIF) pa-

pers and the *Poverty Alleviation Paper (PAP)*. The *Malawi Vision 20:20*'s section 1.5.3 points out that one of its strategic challenges is "how to strengthen self-reliance and community participation in local development programmes". Section 1.5.10 of *Education Policy Investment Framework* (PIF) mentions that "The Ministry will thus encourage the strengthening of the participation of parents and other local stakeholders in the financing and governance of individual schools…" However, when the policy was being formulated, key stakeholders such as parents, local NGOs, Teachers, and School Committees were not adequately consulted (Rose, 2003b). Some of the objectives of the *Poverty Alleviation Paper (PAP)* are: "to improve the access of the poor to priority services and to enhance the capacities of the local communities in managing development" but in keeping with similar documents elsewhere that are part of SAP policies, little in the rhetoric suggests that the burden of payment is to be placed on the poor/rural recipients of the policy.

As already mentioned, the establishment of Community Day Secondary Schools (formerly Distance Education Centres) was seen by government policy makers as essential to broaden access to secondary school education for most primary school graduates. All government secondary schools that are centrally controlled are referred to as conventional secondary schools. However these were seen as expensive to run and they are also few in number. In order to increase the number of secondary schools so as to effectively absorb the growing number of primary school graduates, the government policy decision was to introduce Community Day Secondary Schools. Initially, the few existing Distance Education Centres were converted to Community Day Secondary Schools. Later on the communities were given the authority to construct Community Day Secondary Schools in their locality with minimal government assistance. Specifically, the official announcement in 1998 by the government/Ministry of Education, in relation to creation of Community Day

Secondary Schools was as follows: (i) all DECs would henceforth be known as Community Day Secondary Schools (CDSSs); all CDSSs would fall under the Ministry of Education, as do conventional secondary schools, and not under the Malawi College of Distance Education; (ii) ultimately, student selection for CDSSs would be on the same basis as students to other normal secondary schools; due to time constraints the intakes for Form 1 students in 1999 would be selected by the MOE but in subsequent years selection would be phased to the district level with direct community involvement within the district in the selection process; (iii) the Ministry of Education would begin the deployment of Diploma and graduate teachers to the CDSSs; (iv) all CDSSs would be provided with financial assistance to enable them to obtain basic instructional materials packages on the understanding that communities would also contribute towards the purchase of such materials; (v) permission to open a CDSS would be granted only if MOE standards are strictly followed; (vi) standardized management and financial systems would become mandatory for all CDSS and conventional secondary schools; (vii) this move to convert the former DECs into the new CDSSs, would have a continued emphasis on community involvement in schools.[4)]

As the last point in the announcement above shows, the government envisage a "continued emphasis on community involvement in schools". This is the main feature of Community Day Secondary Schools that distinguishes them from Conventional Secondary Schools.

6. Policy Crisis/chaos within the Community Day Secondary School sector

The Malawi Growth and Development Strategy (MGDS), an overarching policy document for the government of Malawi, acknowledges the various

challenges in the education sector emerging from previous policy initiatives. Specifically, the MGDS[5)] states that:

> [S]ome decisions which have been taken over the past few years, have negatively affected the quality and relevance of the education being provided. The sudden declaration of the Free Primary Education Policy, the conversion of the former Distance Education Centres (DECs) to Community Day Secondary Schools (CDSS) and the use of untrained and under qualified teachers in the system due to inadequate number of professionally qualified teachers, affected the quality of education at both primary and secondary levels.

In other words, Community Day Secondary School sector has been encountering serious problems, which include (taking into consideration the overlaps in education policies, some of the problems highlighted include the other educational sectors and not CDSS only): lack of community participation; poor standards/quality of education; increased dropout in the number students and decline in the number of qualified teachers; and poor housing and school infrastructure.

6.1. Lack of community participation

The establishment of Community Day Secondary Schools is meant to be largely community driven through the already existing local development projects. The government is supposed to provide the learning materials, teachers and other related resources. A study by MacJessie-Mbewe (2004a) explores the relationship between rural schools and rural communities in Malawi as well as the extent of community participation. The study reveals that "there is lack of school involvement in the communities though the communities are

greatly involved in the school development activities" (MacJessie-Mbewe 2004a). Among other studies, two studies by Rose (2003a; 2003b); see also note 2; stand out as authoritative in relation to Malawi community participation in education. From these studies it can be deduced that some of the problems that have emerged in this participatory approach include: non-empowerment of women, exploitation in the participation process, misunderstanding of the difference between participatory democracy and representative democracy and lack of clear guidance and training on participation.

6.1.1. Non-empowerment of women

The general issues of community participation in education in Africa in relation to gender is closely examined and discussed by Rose (2003a). In her study, she "examines whether community participation in education, as an end in itself, is contributing to the transformation of gender relations". The significance of Rose's study[2)] is that she discusses various forms of community participation in education and their corresponding consequences. Above all, she cites examples from Malawi which persuasively demonstrate that community participation in education in Malawi, as well as Africa, regressively affect the empowerment of women. The study revealed that women do not have decision making powers in Malawian community school committees and the unintended consequence is that earlier successes on women empowerment are being progressively eroded. Although not specifically focusing on decision making itself, Maluwa-Banda (2004), also argues that the introduction of community day secondary schools has led to gender imbalance in favour of boy students. While focusing on the gender component of the policy, Maluwa-Banda's (2004) reveals that while "significant progress has been made at policy level to introduce gender-sensitive educational policies…the main challenge has been to put the gender-sensitive policies into practice in the school management and learning."

6.1.2 Lack of clear guidance and training on participation

Community participation largely depends on school committees. However, there is no clear guidance of what committee members are supposed to do and they also lack appropriate training (Rose, 2003a). In some cases students have failed to attend school due to inability to make development "contributions" by their parents. Parents/communities are often not involved in deciding about their contribution how the funds are to be spent. Partially funded school projects by externally institutions such as MASAF do not enhance participation because the communities regard them as burdensome when they demand the communities to honour their contributions.

6.1.3 Exploitation in the "Community Participation" process

Rose (2003a) acknowledges that the terms "community" and "participation" are highly debatable, and she practically demonstrates from Malawian cases, that this lack of clarity on the definition has led to its manipulation by policy makers and implementers to achieve the intended goals. Rose's (2003a, 2003b) studies unreservedly show that the popular notion of community participation tends to produce unintended outcomes often marked by exploitation and inequality.

Rose (2003a) argues that community school committees are not directly involved in school affairs and only limit themselves to "development work" and even in these development works, it is teachers who decide what has to be done; thus community members are not *genuinely* involved in decision- making.

6.1.4. Misunderstanding of the difference between participatory democracy and representative democracy

There is lack of interest in communities in participation of school or other development activities after the 1994 democratic elections due to a misunderstanding of the difference between participatory democracy and representative democracy. As Rose (2003a) puts it, "people feel that, through participating in elections, they have passed responsibilities for schooling to those they have elected".

6.2. Poor standards/quality of education

According to the observation made by Gwede (2004), the quality of education in CDSS (especially in Mulanje district) has significantly declined over the period from 1994 to 2004 as a consequence of the new CDSS policy. Some of the causes of this decline are attributed to lack of qualified teachers and lack of adequate learning-teaching resources. According to Craig[1)] most teachers in CDSS were trained to teach the primary school curriculum and they find it very difficult to handle the secondary level education. Furthermore, "some even teach subjects that they themselves did not pass at MSCE…they usually absent themselves because they are afraid of embarrassment." Although it is well acknowledged that supervision can have a positive impact on student academic achievement, it has been noted that most secondary school teachers are not supervised. According to an observation made by Kadzamira[1)] "even a minimum of one visit to a school per year is not being met; many schools are visited once every 2 or 3 years".

6.3. Increased dropout in the number students and decline in the number of qualified teachers

The Centre for Educational Research and Training (CERT)[1)] points out that the number of CDSSs students by 2004 had significantly declined by 20.9%. The main reason for the dropout is that parents and guardians are less willing to send their children to these schools which are generally viewed as of mediocre state. Apparently, when some students are selected to these schools, parents opt for particular private schools where standards are seen to be far much better than CDSSs.

Although the government mentioned that it "would begin the deployment of Diploma and graduate teachers to the Community Day Secondary Schools", by 2000 this was largely not achieved. In general, although the number of teachers increased by 83% from 5,905 in 2000 to 10,805 in 2005, only 23% of these were qualified.[1)] Interestingly in CDSSs' the number of qualified teachers had significantly decreased from 45.1% to only 7%. In 2007, of the 4,813 teachers in CDSSs, only 930 were trained (19.3%).[6)]

A specific case highlighting this problem is captured in an article that appeared in the *Malawi News* of 24 Feb-2 March 2007. The article entitled *Ugly face of education at Nampthungo CDSS: Two teachers man Form 1-4,* states that at Nampthungo CDSS, enrolment has plummeted just because there are extremely few teacher: two teachers only manning four classes. Some of the reasons for this shortage of teachers include lack of teachers' houses and lack of office space. Interestingly students who had been asking for transfer "have been denied to do so and *this led to chaos*"[7)] (emphasis added).

6.4. Poor housing and school infrastructure

The accommodation for community day secondary school teachers is largely in a pathetic situation which leads to poor quality of teaching services.

More importantly, the school structures themselves are often constructed by community members without serious regard to quality hence they end-up appearing as "temporary" structures. Most of them don't have a library, recreation or sanitation facilities. A study by Volunteers Service Organization (VSO)[8] captures this scenario as articulated below:

> [M]ost schools had basic infrastructure only, many were dilapidated and neglected. Typically, classrooms were old, dusty and equipped with at most a chalkboard and a limited number of desks and chairs. Often they did not have glass in the windows, and were vulnerable to prevailing weather conditions: leaky in the rainy season, stifling during hot summer months, freezing in winter. Teachers" housing mirrored this pattern, with teachers frequently inhabiting dwellings that suffered from poor maintenance and infrastructure and lacked electricity, running water, good sanitation and cooking facilities.

7. Underlying order within the crisis

Despite the crisis and chaos in the Malawi education system as highlighted above, there is demonstration that the system is moving towards a self regulating mechanism which will ultimately create an orderly complex education system. These positive moves towards underlying order are: Decentralization of the education sector; Construction of boarding facilities for girls in some CDSS; Increase in the number of tertiary teacher training institutions; Established the Teacher Service Commission and increased programmes for teachers' welfare; Political commitment and significant budgetary allocation to the education sector; Increased access to secondary school education; Improved management through cluster system.

7.1. Decentralization of the education sector

In order to enhance efficient and effective decision making, the government embarked on ~~an over~~ a decentralization policy in all its sectors including education. In this regard, the Ministry of education is divided into six administrative education divisions. The Southern region of Malawi has three education divisions (each division is comprised of several districts), namely: Shire Highlands Education Division; Southeast Education Division and Southwest Education Division. In the Central region, there are Central West Education Division and Central East Education Division. The Northern region has one education division called the Northern Education Division. Each division is headed by the Education Division Manager (EDM) and below him/her is District Education Manager (DEM). Furthermore, for effective administration and management, secondary schools in each division are grouped together (between 7 to 15) in what are called clusters. This comprehensive decentralization has had a positive impact on education management especially for CDSSs. Gwede (2004) supports this assertion by arguing that "decentralization of the education system is, therefore, of paramount importance with regard to the administration and management of CDSSs in Malawi." He also adds that "It means giving the local community, thus from where pupils come, an opportunity to participate in the management of these schools."

7.2. Construction of boarding facilities for girls in some CDSS

In order to discourage increasing drop-outs amongst girls, the government has started the construction of boarding facilities for girls in some CDSS. So far the communities have welcomed such moves and although it is too early to assess, it likely that the large drop outs that were previously witnessed will be a thing of the past. The project that started in 2007 and spent MK 800 million by June 2007, intends to build more than 20 girls hostels as a way of empowering females through education and started with the first phase

of 7 schools.[9] These hostels are going to be built in CDSSs and will be accommodating 420 female students. All this is inline with the MGDSs' key strategy in education to "Improve the teaching-learning environment to reduce absenteeism, repetition and dropout rates for both sexes."[5]

7.3. Increase in the number of tertiary teacher training institutions

Shortage of secondary school teachers has largely been attributed to limited number of tertiary institutions offering degree programmes in education. The University of Malawi was for a long time the only institution offering this degree programme (while Domasi College of education has been offering diploma programmes). Recently, the government added one public university, Mzuzu, which among other programmes, its main intake is in education. Apart from these public institutions, there has been a major increase in the number of private tertiary institutions which mainly target education courses: Lakeview College, Livingstonia University, Catholic University (although currently not fully credited, plans are underway to ensure that they are monitored by the newly instituted Malawi National Council for Higher Education). In another effort to further increase the number of qualified secondary school teachers especially in CDSSs, the government through donor funding introduced distance learning through Domasi College. In this programme, CDSS teachers who are unqualified go through a three-year distance education in various areas and are upon successful completion awarded a diploma. The programme has so far witnessed a major increase in the number of qualified teachers being deployed in CDSS. Related to this development is the government effort through assistance from USAID in capacity building for key education sectors: Malawi Institute of Education (MIE), Malawi National Examination Board (MANEB), Ministry of Education, University of Malawi and Domasi College of Education. Several officers were identified from these

institutions to undergo further training (Masters and PhD studies) and this ~~has~~ undertaking has greatly improved the capacity of the said institutions.

7.4. Established the Teacher Service Commission and increased programmes for teachers' welfare

Lack of teachers' welfare has been one of the main reasons why most of them have been abandoning their profession (especially at secondary school level). The government recently established the Teacher Service Commission so as to ensure that the welfare of teachers is adequately addressed. The commission is responsible for among other things the recruitment, promotion, discipline and analyzing the conditions of service of all government teachers in the country. Previously, these issues were handled by the Civil Service Commission. The problems that were commonly being experienced by teachers is that the civil service had overgrown to the extent that the welfare of teachers were being neglected or overlooked. In November 2008, the government secured a K7 billion (USD 50million) World Bank loan to construct 1,000 teachers' houses across the country.[10] The government also set in the 2007/2008 budget some money "to pay all arrears to teachers to uplift morale and that HIV positive teachers, numbering 3,000 would be getting K4,000 extra money each month."[11]

7.5. Political commitment and significant budgetary allocation to the education sector

The government has also showed keen interest in the development of the education sector in general. There has been a significant budgetary allocation to the Ministry of Education such as a 14.1% of the total national budget in 2007/8 and 12.5% for the 2008/9 period.[10] And in 2008 alone, 30 CDSS have been targeted to be provided with libraries, teachers' houses and science

laboratories.[10)] This is a major breakthrough for the CDSS that have dilapidated and archaic infrastructure. In the State of Nation Address in May 2008 under the theme, "Malawi: A Nation of Achiever", the President recognized the important role that education plays in national development. Among other things, he promised: upgrade teachers to Diploma, Bachelors or Masters degree levels; and construct hostels at 10 girls secondary schools.[12)] In the 2007/8 budget, the government set apart some funds "for hardship allowances for teachers as a way of luring them back in public schools."[11)]

7.6. Increased access to secondary school education

Although MacJessie-Mbewe (2004b) argues that the introduction of Community Day Secondary Schools has not adequately helped to address the question of secondary school access in Malawi, the available data shows otherwise. Enrolment in DECs in 1998 (just before they became Community Day Secondary Schools) was 132,455 and 1999 after the introduction of the new policy, the enrolment increased to 166,781. Gwede (2004) notes that the largest number of the pupils in secondary schools is enrolled in CDSSs

7.7. Improved school management through cluster system

Trigu (2004) investigated on the impact of Malawi Secondary School Cluster System (a form of decentralised system of school management) on the management of CDSSs in Blantyre district. Trigu (2004) found that the cluster system brought about visible and positive changes in the management practices of CDSSs. Some of the indicators of this improved management include availability and management of school records, sound financial management practices, improved supervisory skills as well as improved community participation. In relation to community participation, Trigu defines it in the context of the Parents-Teachers Association (PTA). In order to measure community

participation he focused on two indicators: the extent to which the PTA assisted the school projects as well as disciplining of students.

8. Conclusion: lessons from chaos-complexity theory in the Ministry of education's CDSS policy

It can be deduced that the education policy of introducing CDSS was followed by a crisis in the sector as evidenced by poor quality and irrelevance of the education being provided. However, confirming the chaos-complexity theory, the education system has not been passive as it has witnessed a re-emergence of several innovative ways of solving the said crisis. This concurs with Kershaw & Safford (1998) who argue that "this ability to deal with complex and dynamic natural systems suggests strongly that chaos theory has the ability to reveal the underlying regularities in the emergent relationships between educational providers and their student". Specifically, some of the lessons learnt from underlying regularities in the education sector emerging from chaos-complexity theory can be summarized as followed.

First, there is a notable innovativeness in the education system. Most of the education programmes that the government is currently engaged in are response to the free-primary education policy and subsequent creation of CDSS. Without the creation of CDSS probably these positive outcomes couldn't have emerged; such as establishment of the Teacher Service Commission and introduction of cluster system.

Second, more and more CDSSs are being established in the country (thus increasing access) and each school being established takes into consideration the lessons and observations made on other previous schools. Ultimately, improved quality of education will be attained.

Third, the earlier education crisis led to an increased number of private and NGOs partnering with government in the area of education examples are GABLE, Civil Society Coalition for Quality Basic Education etc. In addition,

there are now more opportunities for context specific education policy implementation within the said decentralized sector.

Fourth, unlike in the past, there is an increased public interest, awareness and participation in the education sector. This general public interest/debate on education policies is mainly generated by the socio-political controversies surrounding the education policies themselves. The media has also significantly contributed to this debate.

Finally, since the Education Act of 1962, there was no strategy for community participation but recently there has been a development of a *National Strategy for Community Participation in School Management.* One possible factor for the development of this strategy is the general chaos that ensued soon after the implementation of free primary education and CDSS policy.

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ANALYSIS OF SCIENCE PROCESS SKILLS IN WEST AFRICAN SENIOR SECONDARY SCHOOL CERTIFICATE PHYSICS PRACTICAL EXAMINATIONS IN NIGERIA

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Abstract. This study analyzes the science process skills in West African senior secondary school certificate physics practical examinations in Nigeria for a period of 10 years (1998-2007). Ex-post facto design was adopted for the study. The 5 prominent science process skills identified out of the 15 used in the study are: manipulating (17%), calculating (14%), recording (14%), observing (12%) and communicating (11%). The results also show high percentage rate of basic (lower order) science process skills (63%) as compared to the integrated (higher order) science process skills (37%). The results also indicate that the number of basic process skills is significantly higher than the integrated process skills in the West African senior secondary school certificate physics practical examinations in Nigeria. It is recommended that the examination bodies in Nigeria should include more integrated science process skills into the senior secondary school physics practical examinations so as to enable the students to be prone to creativity, problem solv-

ing, reflective thinking, originality and invention which are vital ingredients for science and technological development of any nation.

Keywords: physics, senior secondary school, science process skills, Nigeria

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Introduction

The shift from the teacher-centred method of teaching science to child-centred activity based method which encourages and develops in the child the spirit of inquiry; an attempt to make students fully aware as well as understand the ways scientists work; and also the equipping and preparing students for their possible careers in science and technology led to the development of process skills (Akinbobola, 2006). It is worth noting that for science teaching to be meaningful and relevant, it must adequately reflect the nature of science. That is, it must not only be process-oriented, but it should also emphasize the products of science. It should also promote affective reaction to science and stress the attitudes such as honesty, open and critical mindedness, curiosity, suspended judgment and humility which characterize scientists and the scientific enterprise (Akinbobola & Ado, 2007).

Science process skills have been described as mental and physical abilities and competencies which serve as tools needed for the effective study of science and technology as well as problem solving, individual and societal development (Nwosu & Okeke, 1995). The American Association for the Advancement of Science (AAAS) classified the science process skills into fifteen (Bybee et al., 1989). These are: observing, measuring, classifying, communicating, predicting, inferring, using number, using space/time relationship, questioning, controlling variables, hypothesizing, defining operationally, formulating models, designing experiment and interpreting data. According to Ango (1992), science process skills can be classified into two categories as basic and integrated process skills. The basic (simpler) process skills provide a

foundation for learning the integrated (more complex) skills. Basic science processes are vital for science learning and concept formation at the primary and junior secondary school levels. More difficult and integrated science process skills are more appropriate at the secondary and tertiary school levels for the formation of models, experimenting and inferencing. Hence both basic and integrated science process skills are relevant and appropriate at the senior secondary schools level in Nigeria.

According to Bybee et al. (1989) and Ango (1992), the basic science process skills comprised of observing, measuring, classifying, communicating, inferring, using number, using space/time relationship and questioning while integrated science process skills are controlling and manipulating variable, hypothesizing, defining operationally, formulating models, designing experiment and interpreting data.

Physics practical skills are science process skills. They are taught as part and parcel of the physics curriculum. Science process skills are cognitive and psychomotor skills employed in problem solving. They are the skills which sciences use in problem-identification, objective inquiry, data gathering, transformation, interpretation and communication. Science process skills can be acquired and developed through training such as are involved in science practical activities. They are the aspect of science learning which is retained after cognitive knowledge has been forgotten. Using science process skills is an important indicator of transfer of knowledge which is necessary for problem-solving and functional living.

The skills on the graph practical work cannot be completed without creativity. Practical work is not just putting the apparatus together when seen, but it needs planning, designing a problem, creating a new approach and procedure and also putting familiar things together in the new arrangement. This implies that the knowledge of creativity exhibited by candidates in any practical class helps them to manipulate some practical equipment.

According to Giddings & Fraser (1988), achieving the objectives of science practical work depend a lot on the mode of assessment of laboratory work adopted by the teachers and examination bodies. According to them, the mode of assessment directly influences teachers' teaching methods, students' learning styles and attitudes towards practical activities.

The West African Examinations Council (WAEC) makes use of practical test/examination to assess students' acquisition of various physics practical skills. In these tests, students are required to carry out certain physics practical activities following some given instructions. The scores of the students obtained through the marking of their practical works indirectly indicate the levels of physics practical process skills they could demonstrate during the practical examination. This mode of assessment is also adopted by physics teachers who prepare the students for Senior Secondary School Certificate Examination (SSSCE). This mode of assessment influences the teaching methods adopted by teachers. Also, students' learning style is influenced in such a way that they always try to find certain correct responses or answers irrespective of the procedures adopted.

The process approach method of teaching science is meant to foster inquiry and manipulative skills in students and discourage rote learning. This method embraces other methods of science teaching and is mainly activity based, superior to those in which the students are not actively involved in learning process (Akinbobola, 2008). This reason has made the West African Examinations Council (WAEC) and bodies that conduct Senior Secondary School Certificate Examination (SSSCE) to stipulate that practical work should form the basis of teaching. During examination, the practical work is also assessed separately. Currently, physics being one of the physical science taught in senior secondary schools is taught both in theory and practical. In both internal and external examinations, practical physics is assessed separately as an integral part of the subject.

The problem

The basic science process skills are useful in science and non-science situation while the integrated skills are the working behavior of the scientists and technologists. Thus, both basic and integrated science process skills are relevant and appropriate for all science subjects, in particular Physics at the senior secondary schools level in Nigeria. Hence, there is need to find out the level of acquisition of the science process skills and also to identify the science process skills inherent in the West African Senior Secondary School Certificate (WASSSC) Physics practical examination in Nigeria and classify them to various hierarchical levels. Therefore, will the relative percentage of integrated process skills included in the West African Senior Secondary School Certificate (WASSSC) Physics practical examinations be adequate to meet the quest for national development *vis-a vis* scientific technology growth and self reliance in Nigeria?

Purpose of the study

The purpose of this study is to determine the science process skills included in the West African Senior Secondary School Certificate (WASSSC) Physics practical examinations in Nigeria for a period of 10 years. The study is design to achieve the following objectives: (1) to investigate the science process skills included in the West African senior secondary school certificate physics practical examinations in Nigeria; (2) to compare the basic and integrated process skills included in the West African senior secondary school certificate physics practical examinations in Nigeria for a period of 10 years

Research questions

The study sought to provide answers to the following questions: i) what are the prominent science process skills in the West African senior secondary school certificate physics practical examinations in Nigeria; ii) what

are the percentages of basic and integrated process skills included in the West African senior secondary school certificate physics practical examination in Nigeria.

Research hypothesis

There is no significant difference between the number of basic and integrated process skills included in the West African senior secondary school certificate physics practical examinations in Nigeria.

Method

The entire May/June WASSSCE Physics practical examination questions from 1997 to 2006 were studied to identify the science process skills required from the students. All the basic and integrated process skills in the questions were identified. The design adopted for the study was an ex-post facto design. The instrument used for the study was the West African Senior Secondary School Certificate Physics Practical Questions (WASSSCPPQ) across the years 1998 to 2007. The WASSSCPPQ had already been validated and the reliability had been conducted and obtained by the West African Examinations Council (WAEC). The researchers collected the entire alternative A of the WASSSCPPQ and identified all the basic and integrated process skills for each year. Due to the nature of the physics practical questions in Nigeria, the researchers identified 15 science process skills and classified them into basic and integrated process skills. The basic science process skills comprised of observing, measuring, comparing, contrasting, drawing calculating, recording and communicating while integrated process skills comprised of experimenting, investigating, formulating models, deducing, graphing, interpreting and manipulating. The data collected were analyzed using simple percentages and t-test.

Results and discussion

Research question 1

What are the prominent science process skills in the West African senior secondary school certificate physics practical examinations in Nigeria? The analysis is as shown in Tables 1 and 2

Table 1. Basic (lower) science process skills in the West African senior secondary school certificate physics practical examinations in Nigeria across the years (1998-2007)

YEAR	Basic (Lower Order) Science Process Skills								
	O	M	C	CO	D	CA	R	COM	TOTAL
1998	5	3	1	0	1	4	5	4	23/5
1999	6	3	0	1	2	3	3	6	24/5
2000	5	2	0	2	0	7	6	4	26/5
2001	6	2	0	0	0	7	5	5	25/5
2002	3	3	0	0	1	3	7	5	22/4
2003	5	1	1	1	3	7	8	5	31/6
2004	8	7	0	0	0	7	11	8	41/8
2005	7	2	0	0	5	13	6	5	38/8
2006	8	3	0	0	5	8	9	7	40/8
2007	7	5	0	0	4	12	8	8	44/9
Total	60/12	31/6	2/0	4/1	21/4	71/14	68/14	57/1	314/63

* Second figures are in percentages

O = Observing, M = Measuring, C = Comparing,
CO = Contrasting, D = Drawing, CA = Calculating,
R = Recording, COM= Communicating

Out of the 500 science process skills identified within the period of 10 years (1998 – 2007) in the West African senior secondary school certificate physics practical examinations in Nigeria as shown in Table 1 and 2, the prominent science process skills are manipulating with a total frequency of 86(17.20%), calculating with a frequency of 71 (14.20%), recording with a frequency of 68 (13.60%), observing with a frequency of 60(12.00%) and communicating with frequency of 57(11.40%). This implies that out of the 15 science process skills used in this study, manipulating skill is the only prominent skills from the integrated (higher order) process skills while calculating,

recording, observing and communicating skills are basic (lower order) science process skills. The implication is that only 5 out of 15 science process skills are prominent within the period of 10 years (1998-2007) in the West African senior secondary school certificate physics practical examinations in Nigeria.

Table 2. Integrated (Higher) process skills in the West African Senior Secondary School certificate physics practical examinations in Nigeria across the years (1998-2007)

YEAR	Integrated (Higher Order) Process Skills							
	M	E	G	D	I	F.M	IN	TOTAL
1998	9	2	3	6	1	0	2	23/5
1999	10	1	3	1	6	1	0	22/4
2000	5	0	3	3	0	0	0	11/2
2001	6	3	3	3	1	0	1	17/3
2002	10	1	3	3	0	0	0	17/3
2003	10	0	3	3	0	1	0	17/3
2004	7	2	3	3	0	0	0	15/3
2005	8	4	3	3	0	0	1	19/4
2006	11	5	3	5	0	0	1	25/5
2007	10	5	3	2	0	0	0	20/4
Total	86/17	23/5	30/6	32/6	8/2	2/0	5/1	186/37

*Second figures are in percentages
M= Manipulating, E = Experimenting, G = Graphing,
D = Deducing, I = Investigating,
F.M = Formulating models, IN = Interpreting

Research question 2

What are the percentages of the basic and integrated science process skills included in the West African senior secondary school certificate physics practical examinations in Nigeria? The analysis is as shown in Table 3.

Table 3. Summary of the basic (lower order) and integrated (higher order) science process skills in the West African senior secondary school certificate physics examinations in Nigeria across the years (1998-2007)

S/N	Basic Process Skills	F(%)	S/N	Integrated Process Skills	F(%)
1.	Observing	60(12%)	1.	Manipulating	86(17%)
2.	Measuring	31(6%)	2.	Experimenting	23(5%)
3.	Comparing	2 (0%)	3.	Graphing	30(6%)
4.	Contrasting	4(1%)	4	Deducing	32(6%)
5	Drawing	21(4%)	5.	Investigating	8(2%)
6	Calculating	71(14%)	6	Formulating Mod-els	2(0%)
7	Recording	68(14%)	7	Interpreting	5(1%)
8	Communicating	57(11%)			
	Total	314(63%)		Total	186(37%)

F= Frequency

The analysis in Table 3 shows that, among the basic (lower order) science process skills identified in this study, calculating was rated highest with the frequency of 71 (14%), seconded by recording with the frequency of 68(14%), followed by observing with the frequency of 60 (12%) and closely followed by communicating with the frequency of 57(11%). Other basic science process skills are rated low. These include drawing with the frequency of 21(4%), contrasting with the frequency of 4(1%), and comparing with a frequency of 2(0%).

The analysis in Table 3 also shows that, among the integrated (higher order) science process skills identified in this study, manipulating was rated highest with the frequency of 86 (17%), seconded by deducing with the frequency of 32 (6%), followed by graphing with the frequency of 30(6%) and experimenting with the frequency of 23(5%). Other integrated science process skills are rated very low. These include investigating with the frequency of 8(2%), interpreting with the frequency of 5(1.00%) and formulating models with the frequency of 2(0%).

From the results presented in Table 3 above, it was observed that there was a high requirement made of the basic science process skills than the integrated science process skills in the West African senior secondary school certificate physics examinations in Nigeria across the years (1998-2007). This is indicated by high percentage rate of the basic science process skills (63%) as compared to the integrated science process skills (37%).

The results presented in Tables 1 and 2 also indicated that there are more science process skills in the last five years (2003-2007) than the first five years (1998-2002). That is, there is a gradual departure from the general pattern observed in the first five years to a pattern where more emphasis is placed on laboratory work or experimenting and critical thinking. This is in line with the national policy on education (FME, 2004), which aims at consolidating the science process skills knowledge gained in the primary schools and junior secondary schools levels.

Similarly, there was steady emphasis in the requirement of the skill of communicating in the last five years (2003-2007). This is in line with the new approach to science teaching and learning which emphasis on communicating science rather then listening to talks and taking down notes (Akinbobola, 2008). Another obvious pattern is the increased emphasis on the skills of manipulating, drawing, calculating and recording in the last five years (2003-2007). This might be due to the fact that in Nigeria, emphasis has been shifted from the teacher-centered approaches to child-centered approaches of learning such as problem-solving, discovery and inquiry methods (Akinbobola, 2006) and to involve the learner in hand-on-activities in order to acquire appropriate skills, abilities and competencies both mental and physical as equipment for the individual to solve life problems and contribute to the development and growth of the society (Akinbobola & Ado, 2007).

Also, it is from the manipulation of apparatus, materials and equipment during practical that lead to drawing, calculation and give the result that is recorded and hence deduced to give the final result required.

However, in the areas of the process skills of comparing, contrasting, investigating, formulating models and interpreting, there are scanty representations in questions in the years under review particularly in the last five years (2003-2007).

Research hypothesis

There is no significant difference between the number of basic and integrated science process skills included in the West African senior secondary school certificate physics practical examination in Nigeria.The analysis is as shown in Table 4.

Table 4. t-test analysis of the basic and integrated process skills included in the WASSSC physics practical examinations

Process Skills	N	<x>	S.D	DF	t-cal	t-critical	Decision at P<.05
Basic	80	3.93	3.23	148	2.58	1.96	*
Integrated	70	2.67	3.01				

*= Significant at P<.05 alpha level

The analysis in Table 4 shows that the calculated t-value of 2.58 is greater than the critical t-value of 1.96 at .05 level of significance. Hence, the hypothesis which stated that there is no significant difference between the number of basic and integrated process skills included in the West African senior secondary school certificate physics practical examinations in Nigeria is rejected. The table also shows that the number of basic process skills is more than the integrated process skills in the West African senior secondary school certificate physics practical examinations in Nigeria across the years (1998-2007) under review.

This is in line with the findings of Nwosu (1994) that there is very low level of development of skills of inferring, predicting and formulation of models among year one senior secondary biology students. The result is also in line with the findings of Okebukola (1985) that students were given few opportunities to acquire the process skills and such few opportunities were often for the acquisition of the basic skills rather than the integrated science skills. This might be due to the fact that basic process skills can be easily learnt, and readily transferred to new situations unlike integrated process skills abilities that need to be practiced over a period of time and cannot be learned via a 2-week unit in which science content is typically taught in Nigeria. These abilities are closely related to the formal thinking described by Piaget (Tomera, 1974). Tomera (1974) further explains that one way to decide whether someone is concrete or formal is to ask that person to design an experiment to solve a problem. Chiapetta (1976) observes that most early adolescents and many young adults have not yet reached their full formal reasoning capacity. It is worth nothing that many of our senior secondary school students fall within this age bracket. This might be one of the reasons for the West African Examinations Council to set most of their questions on basic science process skills.

Conclusion

The five (5) prominent science process skills identified out of fifteen (15) used in this study are manipulating (17%), calculating (14%), recording (14%), observing (12%) and communicating (11%) in the West African senior secondary school certificate physics practical examinations in Nigeria within the period of 10 years (1998-2007). Out of this, only manipulating skill is the integrated (higher order) science process skill. The result also indicated high percentage rate of basic (lower order) science process skills (63%) as compared to the integrated (higher order) science process skills (37%). The results

also indicated that the number of basic process skills is significantly higher than the integrated process skills in the West African senior secondary school certificate physics practical examinations in Nigeria across the years (1998-2007).

Implications

The significance of the science process skills has led to the expansion of the goal of science education to include an understanding by, and development in the students of these process skills. The basic (lower order) science process skills are useful in science and non-science situation while the integrated (higher order) science process skills are the working behavior of the scientists and technologists. The integrated (higher order) science process skills are important since they are more needed for self reliance, development and problem solving than the basic skills.

Adequate fulfillment of our goals and aspirations of individuals for relevant and functional education demand a reasonable and higher level of acquisition of science process skills since integrated process skills are the bedrock of science and technology. In the light of the findings, it becomes apparent that students' acquisition of high level skills such as investigating, formulating models and interpreting was very low. That is, not much is seen in the higher order skills or the integrated science process skills, which has much to do with reflective thinking, creativity and problem solving. Hence, there is need to increase the number of integrated process skills in the West African senior secondary school certificate physics practical examinations in Nigeria.

Recommendations

In the light of the findings, the following recommendations are made: (1) Examination bodies in Nigeria, especially West African Examinations Council (WAEC) and National Examinations Council (NECO) should include

more integrated (higher order) science process skills into the senior secondary school physics practical examinations so as to enable the students to be prone to creativity, problem solving, reflective thinking, originality and invention which are vital ingredients for science and technological development of any nation. (2) Physics students at secondary schools level should be given the opportunity to handle and manipulate materials, tools and equipment in the laboratories; test their ideas experimentally; collect, compare, and interpret data; formulate models and draw conclusion. (3) Seminars, workshops and conferences should be organized to re-orientate the physics teachers and to instill the awareness to the public on the use and application of science process skills in the nation's growth and development. (4) The present physics curriculum should be reviewed to ensure greater involvement of integrated (higher order) process skills at the senior secondary school level. (5) Guided discovery/inquiry method should be used by the physics teachers to improve students' levels of science process skills acquisition. (6) Governments (Federal, State and Local) should equip laboratories and physics teachers and students should utilize the facilities in such a way that could lead to the development of both basic and integrated science process skills.

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ИСТОРИЯТА НА ХИМИЯТА И МЯСТОТО Й В УЧЕБНОТО СЪДЪРЖАНИЕ ПО ХИМИЯ В СРЕДНОТО УЧИЛИЩЕ

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Резюме. Историята и философията на химията принадлежи на хуманитарната наука в по-голяма степен отколкото към природните науки. Включването на хуманитарни елементи в обучението по химия може да повиши интереса на обучаваните към химията. Учебното съдържание на училищния курс, обаче, в голяма степен зависи от това, какво е включено в държавните образователни изисквания за учебно съдържание. Докато в американските образователни стандарти включването на историята и философията на химията в учебното съдържание и в подготовката на бъдещите учители е императивно задължение, в българските стандарти такова задължение няма. В тази статия се пледира за хуманизиране на курса по химия в средното училище и се посочват предимствата от това, както и се посочват някои от начините за реализация на такава промяна.

Keywords: standard-based approach, state educational requirements, history and philosophy of chemistry, school course of chemistry

Увод

Интересът на младите поколения към изучаването на природните науки (и химията в частност) намалява. Причините за тази негативна тенденция в образованието не са изяснени изцяло. Очаква се, че след период на упадък, свързан с дълъг период на относително човешко благополучие без войни и други социални сътресения, да последва период на възраждане на интереса към природните науки и следващо ново развитие на технологиите, основано върху новите новите научни открития. Това обаче още не се случва.

Химията в представите на широки обществени кръгове се възприема като трудна. Учебното съдържание на училищния курс по химия подхранва това усещание. Информационният баланс, абстрактите теории от микро- и макро- света и системното игнориране на учебния химичен експеримент ограничават в голяма степен броя на учениците, които биха насочили своите интереси към този предмет, особено в сегашното меркантилно време, когато перспективите за успешна и добре платена кариера на полето на науката не изглеждат окуражаващи. В учениците не рядко битува и превратна представа за хората на науката като хора, вторачени в своите занимания, без широки социални контакти и други интереси. Несъмнено природните науки ще останат желана територия за млади хора с аналитична нагласа на мисълта. Такива хора обаче никога не са били особено много на брой.

Важна задача на изследователите в областта на теорията и методологията на преподаването и обучението по естествените науки и математика е да предложат инструменти и подходи за разширяване на кръга на учениците, които биха насочили вниманието си към природните науки. Изглежда естествено, че включването на хуманитарни елементи в обучението по химия може да има положителен ефект. Вътрешната история на химията (историята на химията като наука) и външната

история на химията (взаимодействието на химията с останалите науки и обществото в исторически план) може да ангажира вниманието на по-широк кръг обучаващи се над тези, които имат аналитично мислене и за които химията е естествена територия (Toshev, 2006). Включването на историята и философията на науката в обучението по природните науки в средното училище ще улесни междупредметните връзки и се очаква да доведе до разбиране на същността и механизмите на световния научен процес (Matthews, 1994; Bybee et al., 1991) – една задача, която у нас никога не е стояла на дневен ред.

С въвеждането на подхода на стандартите (у нас – държавни образователни изисквания) учебната документация и учебниците са в голяма степен стандартизирани. Ново учебно съдържание не би могло да се включи, ако това не е предвидено в държавните образователни изисквания. Затова нашата първа задача е чрез сравнителен анализ на българските и чуждестранните учебни стандарти да преценим дали в българското училище има хоризонт за такова развитие.

От друга страна включването на хуманитарни елементи в обучението по химия едва ли може да разчита на успех, ако учителите не са специално подготвени за това. У нас, обаче, липсва стандарт, който да има характера на списък от умения и компетенции, които трябва да притежават специалистите с висше образование (Тошев, 2001).

Американският опит

Подходът на стандартите (standard-based approach) има за цел да гарантира на всички ученици, независимо къде учат и към кои социални или етнически слоеве принадлежат, добро образование. Такъв е и смисълът на американския образователен закон, озаглавен “No Child Left Behind” (2001). Далечната цел на реформирането на американското училище чрез образователните стандарти е повишаването на научната

грамотност на американското население (AAAS, 1990; NRC, 1996). Научна грамотност означава повече знания и разбиране на предмета на науката, представена чрез физиката, химията, биологията и науките за Земята. Още това означава разбиране на природата на науката и нейната роля в обществото и живота на отделния човек. Тези твърдения може да се разшифрират по следния начин (Matthews, 1994): "знание за основните принципи, закони, представи и факти, върху които се гради науката; познаване на научната методология до степен на използване при нужда; връзка на научните теории с ежедневния живот и разпознаване на химичните, физичните и биологичните процеси в света около нас; чувство за това как науката и свързаните с нея технологии взаимодействат с икономиката, културата и политиката; познания върху историята на науката, за да се разбере как културни, морални или религиозни сили са довели до нейното формиране".

Федералните научни стандарти (NRS, 1996) се отнасят до всички елементи на американската образователна система. Те включват следните стандарти: Science Teaching Standards; Standards for Professional Development for Teachers of Science; Assessment in Science Education; Science Content Standards; Science Education Program Standards; Science Education System Standards.

На щатско ниво също са разработени образователни стандарти, които могат да отчитат и някои особености на областта, където те са валидни. Че бъдещите учители трябва специално да бъдат готвени за внасяне на културни и исторически компоненти в бъдещата си учебна практика, се вижда ясно от следващите примери (Тошев, 2001).

[С]тандарт 1. Учителят по природните науки разбира основните понятия, средствата за изследване, историята и същността на природните науки, за да създаде умения за учене у учениците, които ще позволят различните аспекти на природните науки да се изпълнят със съдържание.

ИЗЯВА (Performances): ... 10. Учителят по природни науки осигурява различни възможности за учениците да осмислят природните науки в техния исторически и културен контекст, използвайки примери от историята и включващи учени от двата пола и различни културни и обществени групи; 11. Учителят по природните науки използва учебни помагала, които илюстрират динамиката на развитието и естеството на природните науки; 12. Учителят по природни науки осигурява възможности на учениците да разглеждат естествените науки като процес на разширяване на знанията, а не като окончателна и не търпяща промяна истина.

ЗНАНИЯ (Knowledge): … 15. Учителят по природни науки знае, че историята на науката помага на учениците да оценят начинанията в науката; 16. Учителят по природни науки знае, че някои периоди в историята на науката са довели до съществени промени в представата ни за света; 17. Учителят по природни науки знае, че науката се променя бавно чрез малки добавки към научното познание и че новите научни идеи, които водят до съществени промени в научното мислене, се възприемат бавно; 18. Учителят по природни науки знае, че с наука са се занимавали най-различни хора, принадлежащи на различни културни и социални общности; 19. Учителят по природни науки знае, че науката е човешки стремеж без оглед на пол, обществена, културна или етническа принадлежност, като развитието на науката разчита на такива човешки качества като аргументираност, задълбоченост, ентусиазъм, сръчност, творчество, интелектуална честност, скептицизъм и отвореност за нови идеи; 20. Учителят по природни науки разбира, че учените са повлияни от своите социални, културни и лични убеждения.

НАГЛАСА (Dispositions): …9. Учителят по природни науки признава и цени приноса на всички учени, независимо от техния пол и принадлежност към определена социална и културна група; 10. Учителят

по природни науки оценява, че науката се развива в даден социален контекст, което внася отпечатък върху постановката на научните въпроси, събирането на данни и формулирането на научните обяснения; 12. Учителят по природни науки признава, че в науката няма безусловни авторитети и че науката е отворена за спорове и дискусии.

Тези примери ярко демонстрират готовността на американските учители за инкорпориране на подходящи примери от историята и философията на науката в учебната си практика в клас.

Българската практика

България още не разполага с пълен комплект образователни стандарти. Подробни списъци от умения и компетенции, които се гарантират на бъдещите учители от висшите училище, където те са учили, още няма. Поддържането на квалификацията на учителите през цялата им кариера е въпрос, който още няма модерно и ефективно решение. Има подозрение, че моделът на подготовка на бъдещите учители не е възможно най-добрият (Тошев, 2001). Разработени са държавни образователни изисквания за учебно съдържание и на тяхна основа са предложени учебни програми за задължителната и профилираната подготовка за IX и X клас (МОН, 2000), по-късно допълнени със съответните програми за XI и XII клас (МОН, 2003). На основата на тези програми са написани и одобрени съответните учебници за училищния курс по химия.

Ето как в тези програми са дефинирани целите на обучението по химия в IX и X клас: „Учениците да придобият система от знания за химичните елементи, веществата, които те образуват, и промените, които се извършват в тях, на нивото на класическите електронни представи...По отношение на знанията: да се задълбочат теоретичните знания за класификация на химичните елементи за строежа на

веществото и за химичните реакции на нивото на класическите електронни представи (за II ниво – квантово-механични)... По отношение на уменията: да се развият интелектуални умения, свързани със сравнение на обекти; обобщения, анализ на системи и ситуации; формулиране на предположения и хипотези.... По отношение на ценностните ориентации: да съдейства за постигане на мотивация за учебна дейност в условията „образование през целия живот", да съдейства за формиране на мироглед и метод на познание, развитие на мисленето, въображението и интелекта на ученика, на творческото начало в неговата дейност...". Ето как са дефинирани целите на обучението по химия в XII клас: „В резултат на обучението по химия учениците ще могат да: описват явления, процеси, свойства, приложението в практиката и физиологичното действие на органичните вещества, както и да разглеждат въпроси свързани със замърсяването на околната среда;...работят в безопасни условия и използват методи за анализ и синтез на органични вещества и продукти, замърсяващи околната среда, както и да оказват първа помощ при работа с такива вещества;... придобитите при обучението по предмета знания, умения и изградени отношения са основа, която ще позволи на учениците да кандидатстват в университетите за обучение по професии, свързани с химични знания, както и в други области на природните науки, където химията не е основен предмет...".

В съдържателен план химията в тези програми е представена статично като набор от факти, които могат да бъдат интерпретирани на по-ниско или по-високо ниво и методи с практическо приложение, които трябва да се овладеят от учениците, защото това ще бъде от значение за следващото им образование и професионална кариера. Нищо от динамиката в развитието на науката като сблъсък на идеи и резултати, или културно-историческите и социалните аспекти на науката във

взаимодействието й с обществото, не би могло да са намери в тези програми. Затова включването на елементи на историята и философията на химията и културните аспекти на науката в учебното съдържание в клас на пръв поглед изглежда невъзможно, но добрият и подготвен в тези посоки учител може да си го позволи, защото изрични забрани относно такъв метод на преподаване всъщност няма в държавните образователни изисквания за учебно съдържание.

Прегледът на издадените в съответствие на държавните образователни изисквания за учебно съдържание учебници показва, че авторите все пак са намерили начин да включат кратки исторически сведения в предлаганите уроци. Отделните уроци на историческа тематика, обаче, са рядкост – има например урок „История на възникването на органичната химия като наука" (Георгиев и др., 2007). В България историята на науката често се разбира като хронологично изброяване на факти или съобщаването на отделни исторически епизоди, обикновено недействителни всъщност, за ангажиране вниманието на обучаващите се. Това, обаче, не е в предмета на съвременното развитие на историята и философията на науката, в което разбира се има периодизация на науката, но основните цели са към разкриване на механизмите и закономерностите на научното дирене (между основните научни списания в областта, например, са: *Ambix. TheJournal of the Society for the History of Alchemy and Chemistry, The British Journal for the History of Science*, *Isis. An International Review Devoted to the History of Science and Its Cultural Influences* или *Foundations of Chemistry: Philosophical, Historical, Educational and Interdisciplinary Studies of Chemistry*). Ето и един несполучлив пример за изброяване на исторически факти (Нейков и др., 2006): „1.5. *Уравнение на Шрьодингер. Водородният атом*. През 1926 г. Шрьодингер въвежда уравнението, което описва движението на електрона. Всяко от решенията му представлява една функция ψ, чиято

стойност е определена за всяка точка от пространството (x,y,z) и за всеки момент t: $\psi = \psi(x,y,z,t)$. Нарича се вълнова функция. Нейният физичен смисъл е разкрит от Борн (1926 г.): квадратът на вълновата функция (ψ^2) е равен на вероятността P(x,y,z,t) електронът да се намира в точката (x,y,z) в момента t. При сложни системи – атом с два и повече електрона, молекула и т.н., уравнението на Шрьодингер не може да бъде решено точно... Уравнението на Шрьодингер за водородния атом се решава точно...” Всичко това трябва да се съобщи от учителя и да се научи (без разбиране) от ученика, при което всеки ученик нормално е да попита: „Какво е това митично уравнение, което никой не показва и защо трябва да помня неща, които се отнасят до този призрачен субект”.

Обсъждане и препоръки

Според Glasersfeld (1993) “ученето започва със създаване на ситуации, където учениците имат възможността да изпитат удоволствието, присъщо на решаването на проблема.” Включването на елементи на историята и философията на науката в учебното съдържание несъмнено създава среда за това и подпомага задържането на интереса на обучаващите се към науката. А това с повторенията си в учебния процес съдейства за формирането на научна грамотност в учениците. Ето как изглежда моделът на връзките между научната грамотност (scientific literacy), учебното съдържание (SCK), историята на науката (HOS) и същността на науката (NOS) (Kim & Irving, 2010):

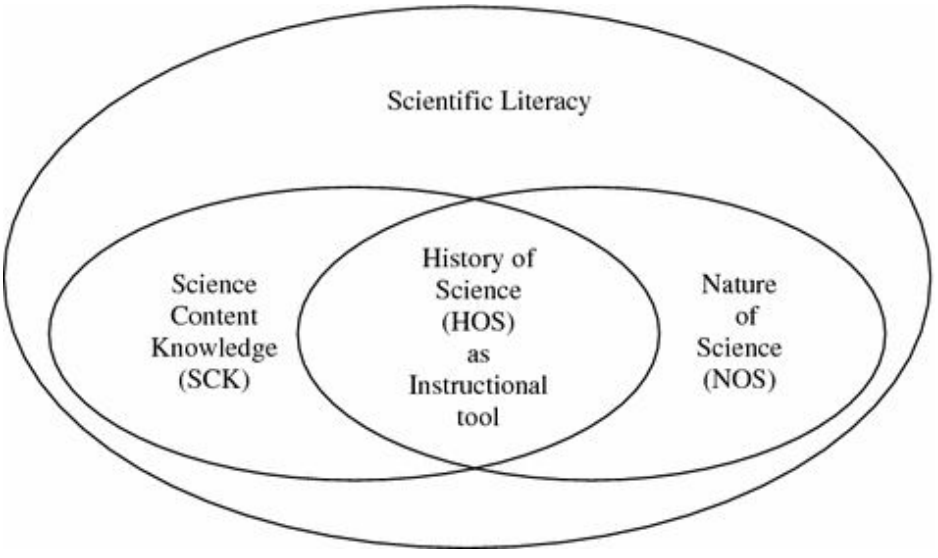

Fig. 1. Връзка между научната грамотност, учебното съдържание, историята на науката и същността на науката.

От този модел следва, че историята на науката може да предложи добри примери, чрез които да се постигне по-добро разбиране, както на традиционното учебно съдържание (SCK), така и на същността на науката (NOS). Ако, обаче, учителите не са подготвени специално за това, практиката показва, че те са склонни да игнорират тази материя в клас, особено при недостига на учебно време и съдържателната обремененост на темите, които трябва да преподават (Tamir, 1989). Предложени са два начина за включване на историята на науката в учебното съдържание (Matthews, 1994): "add-on" – подход и "integrated" – подход. При първия подход учителят предава учебното съдържание според съвременните представи и после го илюстрира с историческите примери; при втория подход историческите факти изцяло са интегрирани в преподаваното учебно съдържание. Дейностите за интегриране на историята на науката в учебното съдържание включват лекции, възпроизвеждане на исторически експерименти, ролеви игри в дебати по исторически теми, включително любопитни епизоди от развитието на науката, драма (Akyol & Himamci, 2007) и накрая четене и

интерпретиране на данни от оригинални текстове с историческо значение.

С държавните образователни изисквания за учебно съдържание се цели в голямата си част учениците да усвоят намиращото се в тях учебно съдържание. В този смисъл се очаква училището да гарантира, че това са научни факти, теории и умения, които неговите ученици притежават след завършване на курса на обучение. Вече се появиха изследвания, които показват, че малка част от учениците в България покриват държавните образователни изисквания за учебно съдържание по химия (Кирова и др., 2010). Навярно такова е положението и при останалите учебни предмети. Затова преработката на държавните образователни изисквания вече изглежда осъзната необходимост. Новите държавни образователни изисквания, обаче, трябва да бъдат изградени върху нова философия, опит за която е представен в настоящата статия. Разбира се държавните образователни изисквания трябва вече да бъдат представени в пълния им обем със стандартизиране на всички дейности и нива в българското образованиие като моделът, който предлага американската образователна система, описан по-горе, изглежда подходящ и за нашите условия.

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HISTORY OF CHEMISTRY AND ITS PLACE IN THE SCHOOL CHEMISTRY

Abstract. History and philosophy of chemistry belongs to the humanities more broadly than to science. The inclusion of humanitarian elements in chemistry education can increase students' interest to chemistry. School subject curriculum, however, largely depends on what is included in the state educational requirements for learning content. The U.S. educational standards include the history and philosophy of chemistry both in curriculum and training of future teachers as an overriding obligation. In the Bulgarian standards

no such obligation is presented. This article advocates the humanization of the course in chemistry in high school and highlights the benefits of this, and mentions some of the ways to implement such a change.

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MOTIVATING STUDENTS' LEARNING USING WORD ASSOCIATION TEST AND CONCEPT MAPS

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Abstract. The paper presents the effect of a free word association test, content analysis and concept mapping on students' achievements in human biology. The free word association test was used for revealing the scientific conceptual structures of 8th grade and 12th grade students, around a stimulus word – human being – and for motivating them to study human biology. The stimulus word retrieved a cluster of associations most of which were based on science education and experience. Associations with the stimulus word were analyzed and classified according to predetermined criteria and structured by means of a concept map. The stimulus word 'human being' was quantitatively assessed in order to find out the balance between the associations with its different aspects. On the basis of the results some connections between biology and other sciences studying the human being, were worked out. Each new topic in human biology was studied by using content analysis of the textbook and concept mapping as study tools and thus maintaining students' motivation. Achievements of students were assessed by means of tests, observation

and concept maps evaluation. The obtained data was also valuable in clarifying the complex nature of the human being, and confirming the statement that biology cannot answer all questions, concerning human nature. Inferences were made about the word association test combined with content analysis and concept map construction as an educational strategy.

Keywords: motivation, word association test, human being, concept maps, content analysis, human biology

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Aims

The study was directed to finding the answer to the following questions: What are the differences between the associations of 12th grade students and those of 8th grade students to the stimulus word *human being*? How do concept maps of associations motivate students to learn? Does content analysis and construction of concept maps, followed by discussion, support motivation and engage students in productive work?

Introduction

The number of students that lack motivation for learning has been increasing of late (McInerney, 2000) and this problem is attracting more and more researchers to study and attempt to solve it. One of the possible reasons for this motivational problem is that they do not possess the skills to learn successfully and find "learning of abstract and highly conceptual nature of science very difficult" (BouJaoude & Attieh, 2008).

Motives are widely defined; at one end they can be incentives or provocations to action, because they induce a person to act (Davidov, 1983). At the other, they can be little more than "hypothetical constructs used to explain why people are doing what they are doing" (Brophy, 2004). On the other hand, the term motivation is a basic category in modern psychology and ethology (Dessev, 1996). Biological motivation is regarded as a complex of

compensatory reactions of animals to disturbances in their homeostasis, e.g. thirst, hunger, breeding and parental behaviors, etc. (McFarland, 1985). Psychological motivation is regarded as a "theoretical construct used to explain the initiation, direction, intensity, persistence and quality of behavior, especially goal directed behavior" (Brophy, 2004). It is caused by a number of motives, such as needs, interests, desires, fears, emotions, attitudes, ideals and values (Davidov, 1983). Each of these motives impels towards achieving one's desired or intended goals (Stamboliev, 1996). The boundaries between affective ("feelings connoting emotional or visceral reactions") and cognitive ("thinking") variables of motivation are considered to be "rather blurry" (O'Neil & Drillings, 1994) though the two are very often contrasted. Certain kinds of behavior are repeated if they remove stress and danger and are assisted with positive feelings as "seeking pleasure is a reflex response built into our genes for the preservation of the species" (Gilbert, 2002). Motivation is a very complex phenomenon, playing a crucial role in learning, whose different aspects are studied by many scholars. Some concentrate on physiological basis of behavior (Maslow, 1943; Levine, 2000, pp. 41-94), others look for the effects of educational motivation (Brophy, 2004); still others study the mechanism of motivation (Gilbert, 2002; Graham, 1994). Motivation is regarded as intrinsic or extrinsic (Schunk et al., 2008) affected by goals, goal orientation and goal settings (Alderman, 2004), directed to achievement and competence (Elliot & Dweck, 2005), essential for classroom activities (Gilbert, 2002), dependant on attribution beliefs, social factors and the social climate in the classroom (Alderman, 2004), etc.

The understanding of motivation is based on knowledge of motivational variables and task characteristics (O'Neil & Drillings, 1994), social mediation of motivational variables (Rueda & Moll, 1994), cognitive control of affective states (Schunk et al., 2008), praise versus blame and reflective self-awareness (Graham, 1994), measures of motivation (McCombs, 1994),

motivation of individuals in team teaching (Swezey et al., 1994) importance of curiosity and exploration (Lehwald, 1991) and so on.

Snow & Jackson (1994) come to the conclusion that instructional learning involves a mixture of cognition, conation and affection or of knowledge, feelings and action. McCombs (1994) studies the role of volition in motivation and proves the importance of persistence (the energy with which an individual pursues a goal) and values (the significance of the goal that the individual will pursue) as key constructs. Rueda &. Moll (1994) study the interpersonal processes within which individual activity occurs. Pintrich (1999) investigates the effect of motivation on self-regulated learning.

The importance of motivation in all aspects of human life and especially in education is the reason for such a great interest in it and for the many theories proposed for its understanding. Based on clarification of motivation from the studied literature, our search was directed to the effect of cognitive motivation on students' learning achievements in human biology by using a word association test as the beginning followed by content analysis, concept map construction and discussion.

Method

Often students are not internally motivated and need situated motivation, created by teachers through special environmental conditions in the classroom. Such motivational conditions were created using word association test. However, arousing motivation at the beginning of the studies is not sufficient for successful learning; motivation should be sustained throughout the whole course of the study. This problem was solved by succeeding word association test with the use of content analysis and concept map construction. The three methods were used consecutively in the process of studying human biology, followed by discussion.

Participants

The sample of investigation involved 80 students in the 8th grade (the end of middle school, 14-15 years old) and 40 students in the 12th grade (the end of high school of secondary schools in Bulgaria). The investigation covered the 2006/2007 school year and was repeated during 2007/2008 school year with students from two secondary schools in Sofia. The 12th grade students participated in the word association test, not in the study of human biology in which the content analysis and concept map construction methods were used. They studied human biology when they were in the 8th grade and enlarged their knowledge of the human being in general biology courses and in humanitarian and technological subjects in the 9th-12th grades. Through the mental picture of a human being that was on top of their minds at the end of secondary school later in life they would percept people they meet. Comparing the mind maps of 12th grade and 8th grade students we wanted to see the dimensions of development of the fundamental concept human being.

Variables: The 8th grade students were divided into three groups (variables): B1 (20 students) – use of word associations for motivation; B2 (30 students) – use of word associations for motivation and demonstrations of concept maps in teachers' presentations; B3 (30 students) – use of word associations, concept mapping by the students for homework, discussion and concept maps improvement in the classroom (see procedure).

Instruments

Free word association test

This is a reliable technique used as a procedure for measuring number, direction and strengths of connections (Novak & Govin, 1984; Mervis & Rosh, 1981).

The ability of the brain to make associations and facilitate learning and intellectual development has been studied and elucidated by many scientists.

Some studied the nature of associations and the mechanisms of their building by the brain (Bain, 1894; Pavlov, 1927). Others directed their investigations to associative memory (Maki, 2007), associability (Suret & McLaren, 2005), associative learning (Levine, 2000, pp. 41-94; Wills, 2005). Still others were attracted by word association technique, cluster analysis and concept or mind map construction in teaching (Smith & Heise, 1992; DiCarlo, 2006; BouJaoude & Attieh, 2007), or by association of emotions and thinking (Field, 2005).

Free word association test requires responses that are not restricted to any specific category or class of words. In tests of discrete word association, each participant is asked to produce only a single associate to each word, while in tests of continuous association, the stimulus word or the list of stimulus words is presented to the respondents only once and they are asked to give as many associations as they can in a pre-specified period of time.

Concept Mapping

Concept mapping is a promising teaching and learning method that enhances students' achievements by helping them to acquire structured knowledge. The human conceptual system is characterized by two main concepts – category and schema (Smith & Heise, 1992; Mervis & Rosh, 1981). The visual representations of these concepts are concept maps (Novak & Govin, 1984), mind maps (Buzan & Buzan, 1993), intellectual maps (Kostova, 1998, 2000). Psychologists, like geneticists who map the genes, map the connections among words which are learned as a result of everyday experience (Nelson, 1996). Maps, especially concept maps, aid learning in all subjects (BouJaoude & Attieh, 2008; DiCarlo, 2006; Smith & Heise, 1992; Marzano, 1997; Suret & McLaren, 2005). In this activity several mental processes are involved: comparison, analysis, comprehension, model construction, elaboration, retrieval, etc. (Bruner, 1960). Conceptual mapping organizes

learning at the level of conceptualization in the sense of the theory of constructivism, the foundations of which were laid by Piaget (1951), (Pintrich, 1999; Rueda & Moll, 1994; Ducret, 2001).

Buzan & Buzan (1993) worked out the basic rules for successful construction of mind maps, incorporating the use of the two hemispheres – logical thinking and imagination. Marzano (1997) proposed different graphical organizers for visual construction of concept maps. Zaller (1992) investigated the dependence of word association test on information (knowledge) and predisposition of the respondents. Word association test creates a stimulating environment for concept mapping. Authors give different wording of a concept map explanation: "a nonlinear diagrammatic representation of meaningful relationships between concepts" (DiCarlo, 2006), "a mental model, a schematic representation, which is a hierarchical structure from interconnected words, ideas, problems, solutions, arranged around a key word in radial circles" (Buzan & Buzan, 1993). We stick to the definition of Buzan & Buzan (1993) and use a concept map as a study tool.

The concept map can represent a structure of concepts, derived from a textbook by means of content analysis or retrieved from the memory by means of association test or brain storming (Novak & Govin, 1984). Concept maps are used to enhance meaningful learning (DiCarlo, 2008) by providing "fixture", support, construction of interconnected scientific words (Suret & McLaren, 2005; Bandura, 1997).

Procedure

*First Step***:** Word association test with 12th grade students at the end of school year 2005/2006 and concept map construction (all students).

Data collecting was done by requiring respondents to write associations with a given word. Each respondent was presented with a sheet of paper and a pencil and was instructed to be ready to write his or her *responses*

(words, phrases, ideas) that came to mind in the same succession as they appeared when hearing a given word. That is, respondents wrote words coming on top of their minds as driven by the *stimulus*. When told the words 'human being'**,** they began making their list for the duration of three minutes. The papers were collected, analyzed (Table 1), concept maps were constructed (Fig.1) using the students' associations with the key word according to chosen criteria. Thus a picture of a 'human being' as seen by 12th grade students was constructed around chosen criteria.

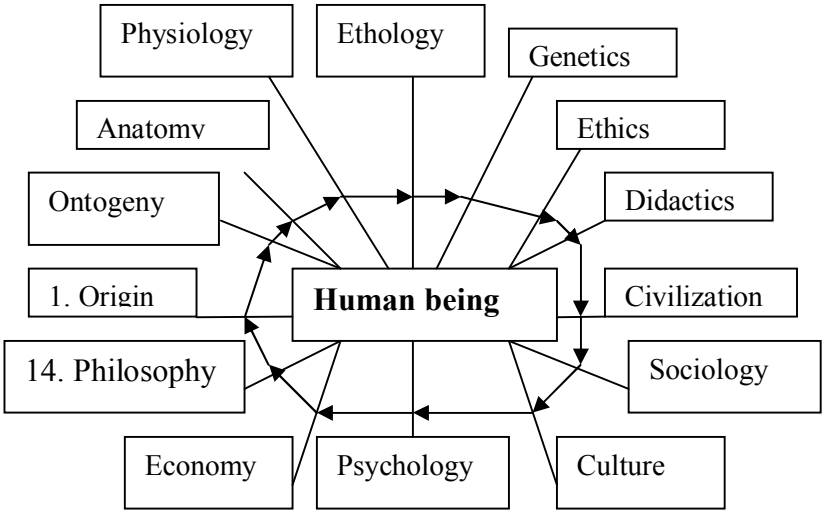

Fig 1. A simplified model of the concept map of 12th grade students' associations

Second step: Word association test, concept mapping and discussion (Groups B1, B2 and B3) at the beginning of school year 2006/2007.

The stimulus words, 'human being', were presented to the target group (the three variables of 8th grade students: B1 – 20, B2 – 30 and B3 – 30) at the beginning of the school year in the biology classrooms of three classes. This was at the first school period of studying the course in human biology, mainly concerned with human anatomy, physiology and hygiene. Students had studied some aspects of the human body in the previous seven grades. Papers were

collected and a concept map for each class of 8th grade students was constructed and visualized. The concept maps of 8th grades were simpler, each not more than 25-30 associations (Table 1).

Table 1. Classification of 12th grade (first figure) and 8th grade (second figure) students' associations with the stimulus word Human being. (No denotes the number of words; figures in brackets denote the repetition number of the word)

Criteria	%	No	Examples	
			12th grade	8th grade
1. Origin and evolution	11/ 8.8	34/8	Struggle for existence, natural selection, living thing (4), adaptation, survival, biological species (5), living system, animal kingdom, mammals (2), monkeys, apes, hominoids, Homo sapiens (6), paleontology, anthropology, history, races, superior creature (3), evolution	living thing (5), animal kingdom, mammals
2. Individual development	4.5/ 9.9	14/9	Man, woman, fertilization, pregnancy, birth, growth, embryo, child, young, youth, adolescent, puberty, adult, death	Man, woman, child, growth, pregnancy birth, young, adult, death
3. Anatomy	8.7/ 16.4	27/15	Complex structure, cell, cellular structure, tissues, organs (4), systems, locomotion system, limbs, skeleton, cranium, cardio-vascular system, respiratory system, alimentary system, excretory system, reproductive system (2), nervous system (3), endocrine system, sensory systems, high functions of the nervous system, brain (2)	Cellular structure, tissues, organs (4), systems, limbs, lungs, stomach (3), kidneys, sex organs, nerves
4. Physiology	10.6/ 17.5	33/16	Living processes, nutrition (2), respiration (2), excretion (2), reproduction, growth, development, irrita-	Nutrition (4), respiration, excretion, reproduction, growth,

			bility, movement (3), memory (logi- cal, visual, short-term memory, long-term memory), thinking, sleeping, dreams, homeosta- sis (temperature, mineral salts, osmotic pressure, hormones, glucose), health (5)	movement (3), health (5)
5. Ethology	5.8/ 4.4	18/4	Values, behavior (in nature, in school, in nature), collaboration**,** tolerance, ethical behavior, respect, care, relationships between men and women, with other people, maternity, playing, cruelty, killer, smile, self-destruction	Behavior, collabo- ration, cruelty, smile
6. Genetics	3.8/ 0	12	Generation, up-bringing, genetic engineering, heredity, variation, gene, dominance, dominant, recessive, karyogram, hereditary diseases, therapy	
7. Ethics	14.5/ 12	45/11	Values, respect of adults, moral, open-minded, caring, gentle, good-natured, responsible, beautiful, learned, optimistic, dedicated, honest, amiable, wise, creative, experimenter, ambitious, innovator**,** strong, researcher, hard working, good, willful, ready to help, bad, obstinate, lazy, idiot, ugly, evil, egoist, dishonest, cynical, distrustful, selfish, narrow-minded, unjust, unpleasant, coward, hypocrite, prudent, pompous, irresponsible, aggressive	Beautiful, honest, strong, good, bad, ugly, selfish, un- just, unpleasant, cow- ard, aggressive
8. Didactics, peda- gogy	6.5/ 5.6	20/5	Upbringing, family, parents**,** text-book, encyclopedia, human rights, history, humanity, development, culture, nursery, school, university, teachers, terrorism, genocide, democracy, anarchy, despotism, pressure	Family, text-book, encyclopedia, teachers, school
9. Civilization	8.4/ 6.6	26/6	Society, history (old, new),	War (2), plants,

			ancient, contemporary, struggle for freedom, war, state (democratic, social), government (2), technology, independence, equality, victim, information, technique, modeling, internet, destruction of nature, plants, animals, food, goods	animals, food, goods
10. Sociology	5.5/ 6.6	17/6	Humanity, society, people, overpopulation, feeding, dependence, home, family, work (job), social creature, thinking being, rich, poor, survival, unemployment, poverty	People, home, feeding, work, unemployment, poverty
11. Culture	5.2/ 5.6	16/5	Music, art, religion, God, reading, writing, language, alphabet, experience, science, writer, profession (3), novelist, studying	Music, art, studying (3)
12. Psychology	9.4/ 4.4	29/4	Psyche, sense, wisdom, soul, stupidity, intellect, thinking (6), cleverness, consciousness, anxiety, emotions, feelings, mind, mistake, wit, fear, help, speech, communication, stress, distress, pleasure, enjoyment, realization	Stupidity, wit, Cleverness, speech
13. Economy	1.6/ 1.1	5/1	Industry, agriculture, budget, financial policy, money	Money
14. Philosophy, Aesthetics	4.5/ 1.1	14/1	Micro-cosmos, conscience, consciousness (3), sensibility (5), world, environment, beautiful, ugly,	Environment
Total	100/ 100	310/91	Average = 7.75	Average = 1.14

For a comparison, the concept map of 12th grade students was presented and then discussed (Table 2). The discussion directed students towards formulation of a hypothesis about the expected benefit from studying human biology.

Table 2. Discussion on the results from the word association test

Questions	Shortened answers
1. How do the two mind maps of 12th grade and 8th grade students differ?	They differ in scope and range. 12th grade students show broader understanding and conceptualization of a human being.
2. What are the reasons for the difference?	Knowledge and experience of 12th grade students are higher.
3. Can biology give all the answers concerning human beings?	No. Many branches of science study human beings (more than 48).
4. What major aspects of a human being should be studied in a course of human biology?	About the origin, structures, functions, and hygiene of the human body and the healthy way of life as well as regulation, integration and responsible behavior.
5. What one might gain from studying human biology?	Knowledge and competences to understand the human body, be healthy and control behavior.

Third step: Studying the introductory lesson to Human biology with the help of content analysis, concept mapping and discussion (Group B1, B2 and B3).

Students in B1 formed four groups of five persons each. The text of the lesson was divided into four paragraphs, one for each group, and ten minutes were given to read and five minutes to discuss and clarify the information between them. They used content analysis but not concept structuring. One member of each group had to explain the studied paragraph and the other members listened carefully and corrected or added points they thought were missing. At the end of the period the teacher then drew their attention to mis-understandings and wrong interpretations.

Students in B2 were given a lecture by the teacher using a concept map (Fig 2), stopping after each paragraph and directing them to the textbook. They were asked to find the correspondence between map and paragraph and write down the concepts, explained by the teacher. Guided in this way they followed first the map, then the explanations and finally the textbook.

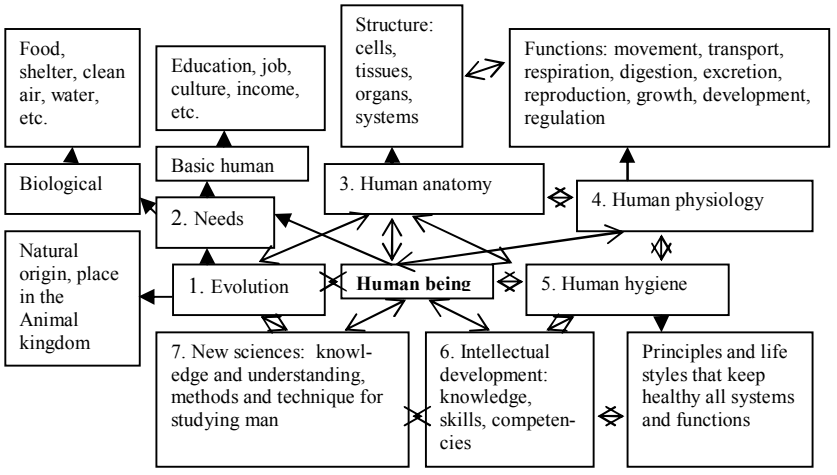

Fig 2. A generalized concept map on the introductory lesson to Human biology, presented by the teacher in G2.

Students in B3 read quickly trough the text, determined the core concept and then with help from the teacher, scanned each paragraph, clarified the concepts, and structured them into a concept map. Then they compared it with the teacher's concept map (Fig 2). A discussion followed to correct students' maps and to enrich each concept with the information added by the teacher. Students' attention was drawn to the associations for a comparison (Fig 1, Table 1). The conclusion they reached from the comparison was that the studies to follow would intend to fill in the gap between the concept map of the introductory lesson and that of 12^{th} grade students' associations helping them understand themselves and others better and keep a healthy life style. This step acquainted students with concept mapping and structuring. It was followed by discussion (Table 3).

Table 3. Discussion on the concept map of the Introduction

Questions	Shortened answers
1. What are the arguments for the natural origin of man?	The similarities in the structure and functions of the bodies of animals and human beings.
2. What are the arguments for the uniqueness of man?	Man can study nature and the whole surrounding world including him and can develop values and action plans.
3. What interrelated sciences give knowledge of man?	Human biology (anatomy, physiology, hygiene, etc.), psychology, cognitive sciences, technology, medicine, etc.
4. What relations between concepts are missing?	Between: biological and basic human needs, evolution and new sciences, etc.
5. What conclusions from the map can you draw?	The human being is an interrelated entity of structures, functions, behavior, emotions and ambitions. He is a unique creature.

Fourth step: Analysis and concept mapping of the topic "The Cell" in the textbook (Group B3).

Students in B3 worked in small groups of two, read the information in the textbook; wrote the concepts in the workbooks and constructed maps (Fig. 3).

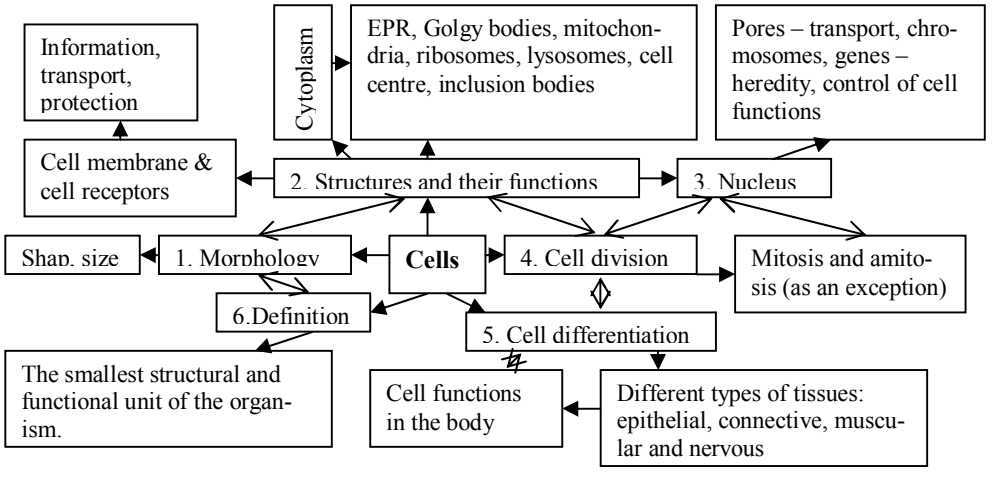

Fig 3. Concept map of the topic"The Cell". There are 32 concepts in the textbook

Following this, a discussion was initiated for clarifying the core concept, the hierarchy of concepts and the connections between them. Each group

participated in the discussion which consisted of presenting its results in analyzing/listing the cognitive structure, making the necessary corrections and reaching more or less a consensus about the concept map structure. All concepts in the map were explained and visualized. Groups B1 and B2 continued to work as in the third step.

Fifth step: Analysis and concept mapping of the topic "The Human skeleton and the bones" (Group B3).

Work was divided between home and classroom. *Work at home*: Each student read the text in the textbook, underlined the concepts and constructed a concept map. 2. *Work in the classroom*: A class discussion based upon prepared questions and directed by the teacher, led to the construction of a consensus concept map and clarification of concepts (Fig 4)

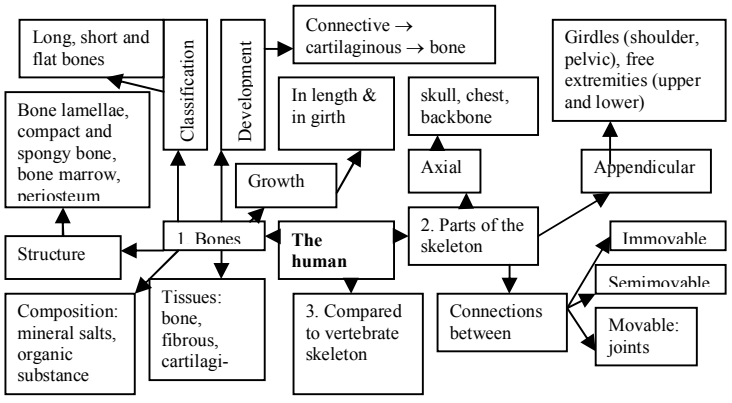

Fig 4. A concept map of the topic 'The Human Skeleton'

Some students illustrated their concept maps with drawings, using Paint Brush or colored pencils of their choice. The concept map helped students in making associations and remembering the structured information, which was evident from their participation in the studies and discussions to follow. Groups B1 and B2 continued to work as in the third step.

Sixth step: Successive studies of the topics in the course "Human Biology" using content analysis, concept map construction and discussion. In the discussion on the bases of the concept maps, connections with other branches of science were made (Table 4).

Table 4. Concept maps constructed throughout the course on Human biology, elaborated by the students in B3 and demonstrated by the teacher to B2 (No – number of concepts in each topic)

Concept maps on topics:	No	Connections with other sciences
1. Locomotive system	55	Evolution, history, taxonomy, technology, chemistry, ethics
2. Cardio-vascular system	48	Medicine, evolution, environment, healthy way of life, ethics
3. Respiratory system	21	Evolution, medicine, physics (diffusion) , chemistry (gases)
4. Alimentary system	42	Evolution, medicine, food, technology, trade, dentistry, diet, alcohol and tobacco trade, etc.
5. Excretory system and Homeostasis	22	Evolution, medicine, technology, cosmetics, fashion, homeostasis, physics, (temperature regulation), etc.
6. Reproductive system and Development	45	Evolution, medicine, birth control, demography, ontology, gerontology, ethology, ethics, sexual abuse, culture, etc.
7. Nervous system	48	Evolution, medicine, drugs, addiction, psychology, cognitive science, ethology, etc.
8. Endocrine system	38	Evolution, medicine, individual development, anabolic steroids, aggression, etc.
9. Sensory systems	60	Evolution, medicine, internet, information sciences, visualization, ethology, ethics, etc.
10. Higher functions of the Nervous system	16	Psychology, didactics, pedagogy, cognition, medicine, ethics, philosophy, media, computer, physics (sound and noise), etc.
Total: 395; Human anatomy: 210; Human physiology: 120; Human hygiene: 65		

The concept map of each chapter integrated scientific concepts of all topics in it, which helped the associative learning and long-term memory. Groups B1 and B2 continued to work as in the third step.

Evaluation instruments

Observation and assessment of students' learning behavior

The learning behavior of students in the three learning conditions was assessed and evaluated using predetermined five criteria included in a specially constructed checklist: responsibility, attention, activity, persistence and valuing of tasks. Assessment of *responsibility* was based on positive attitude to and in-time solution of learning tasks (Schunk et al., 2008) and personal desire for success (Elliot & Dweck, 2005). *Attention* was assessed on the grounds of: focus on tasks, desire for competence (Elliot & Dweck, 2005), enjoyment and willingness to engage in learning activities (Deci & Ryan, 1995; Wright, 1987), intention of acquiring knowledge and self-satisfaction of curiosity (Maslow, 1943). The characteristics of *activity* were: engagement in productive work and supporting the motivational climate in the classroom (Marzano, 1997), competence in concrete learning actions, collaboration and effective communication (Brophy, 2004). *Persistence* was regarded as: need in achieving goals (Maslow, 1943), seeking competence (Elliot & Dweck, 2005), perseverance and self-regulation in pursuing the task to the end (Artino, 2008; Bandura, 1997), esteem needs and confidence in ones ability (Maslow, 1943). *Valuing of tasks* was assessed on the grounds of learning behaviors, such as: valuing outcomes (a grade on a product – test, map, effective participation in discussion), intended learning benefits (conscious competence) (Guilbert, 2002; Nelson, 1996), satisfying the competence need (Field, 2005), and creative self-expression (Maslow, 1943). Each criterion was assessed, a personal quotient was estimated and the results were converted into marks using a scale in order to be comparable with the results from tests and concept maps evaluation. Marking was done using six-point scale from 1 – the lowest to 6 – the highest (Table 5).

Concept map scoring rubric

The concept map is radial, spatial, with increasing concentric circles from groups of words, coming out from a central key word or words as a structure by means of subordination (Buzan & Buzan, 1993).

The skills and competences of students in concept map construction were assessed using six criteria included in a checklist and arranged in levels according to successive actions and difficulty. 1) *Core concept correctly chosen*: After reading and analyzing the text, the students identified the main concept (clarified by all other concepts), and placed it at the centre of the map. In some cases they used more than one core concept at the center of the map. For example in the concept map on human excretory system they used two core concepts – kidneys and skin, and made two clusters of concepts on the map. 2) *All concepts correctly chosen* and included in the map: Students had to find out the concepts, pertaining to core concept and the topic, explained in the text and clarifying the main ideas. They retrieved the concepts from the studied text but not from a given list of words (BouJaoude & Attieh, 2008) and arranged them in a map. This they did by reading, copying the concepts in the workbooks and trying to understand the meaningful connections between them. 3) *Concept hierarchy correct*: Around the core concept students arranged the auxiliary concepts directly connected with it, in the first circle. They gave a sign of the beginning of the circle (for example, Fig 2, "1. Evolution"), which corresponded to the first paragraph of the text. Then they arranged the concepts usually clockwise, thus indicating how the map should be read. Some students (very few) arranged the concepts in the opposite direction, which was also considered correct. After that they arranged the concepts of the second circle, which clarified the concepts in the first circle and so on. 4) *Connections correct*: Using arrows, students showed connections between concepts. The direction of the arrows indicated causal direction of influence and logical structure of the concept map. This is the heuristic value of the

map. The map as a tool of visual construction helped them discover the links of concepts in a unified conceptual structure. 5) *Successive structure according to text correct*: this was accomplished by careful reading and comprehension of the information in the text by comparison, analysis, synthesis, abstraction, generalization. The development of the map corresponded to the logic of the discussed main scientific problem. 6) *Aesthetical visualization*: the signs by means of which the map attracted attention – letters, arrangement, graphic organizers, illustrations, drawings, pictures, etc. Students were warned not to overburden the maps, but to make them readable and useful in facilitating text understanding and comprehension (A picture is worth thousand words). Each criterion was assessed and an individual scoring was devised. According to a scale, each student achieved a mark from one to six, thus individual concept map mean scorings were obtained. On the bases of individual mean scorings the total mean of each group was calculated (Table 6).

Biology achievement tests

Pretest (Appendix 1) and Posttest (Appendix 2) were used to measure students' achievements. Each test contained 30 items (5 items for each level of Bloom (1969) Taxonomy of educational objectives. The characteristics of the tests were assessed (Table 7) and the items having unreliable characteristics discarded. The pretest was applied at the beginning of the course and the posttest – at the end. The two tests were given to the three variables under the same conditions. The results were assessed for each level of Bloom's taxonomy (Table 8).

Results and interpretations

Associations with the words 'human being'

The stimulus words 'human being' evoked lots of connections to other words. The total number of them was 310 and the average number of associa-

tions per a 12th grade student was 7.75 (Table 1, Fig. 1). The total number of associations for 8th grade students was 91 and the average number 1.14. All students responded to the test according to their individual flexibility of remembering, knowledge and type of memory. Some students started to write at once, others were delayed with the response. The reason probably was the very complex meaning of the stimulus word, discussed in many school subjects – biology, history, geography, psychology, philosophy, technology, etc.

The analysis of concept maps of 12th grade and 8th grade students based on their associations is represented in Figs 5 - 7.

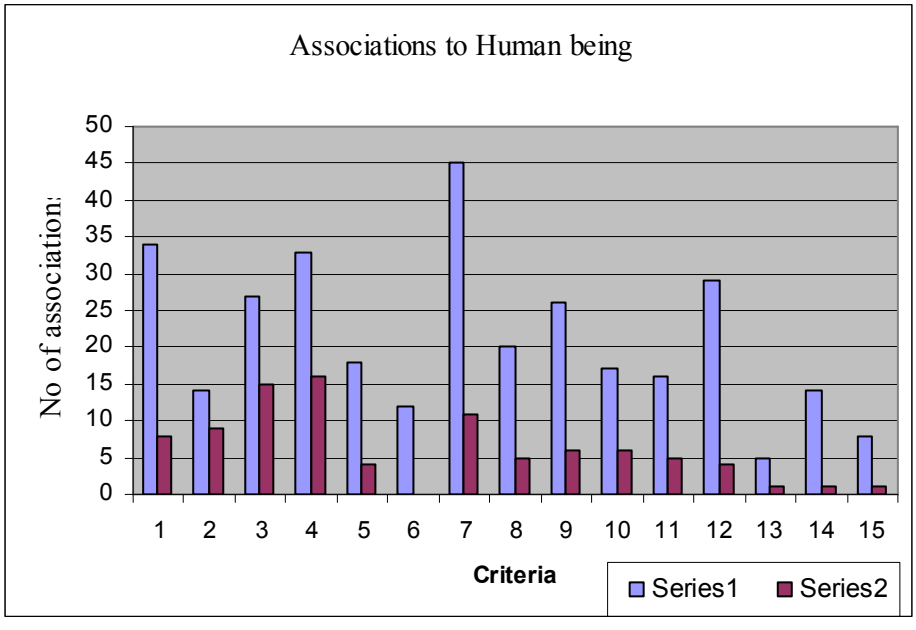

Fig. 5. Number of associations to the stimulus words 'human being': series 1. 12th grade; series 2. 8th grade; Criterion 15 – average of the associations of 12th and 8th grade students

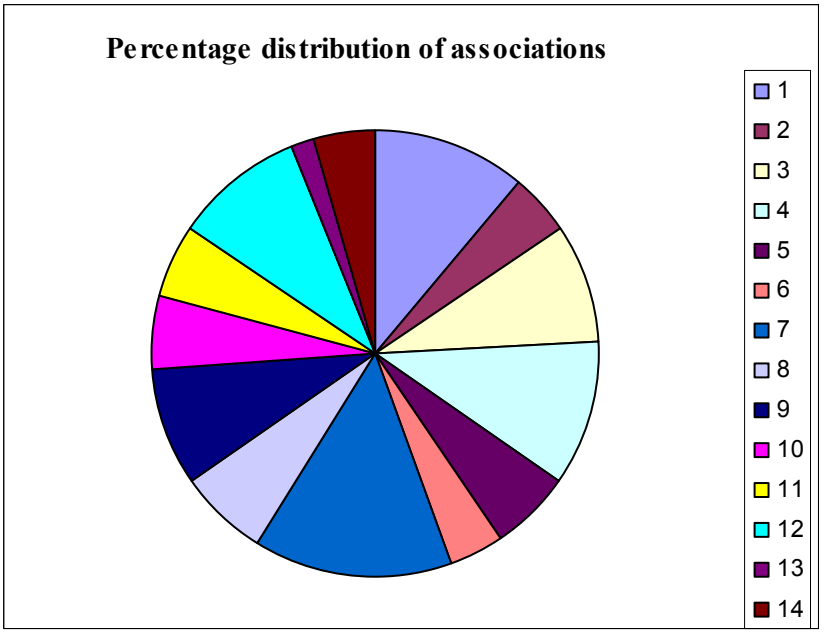

Fig 6. Percentage distribution of associations of 12th grade students

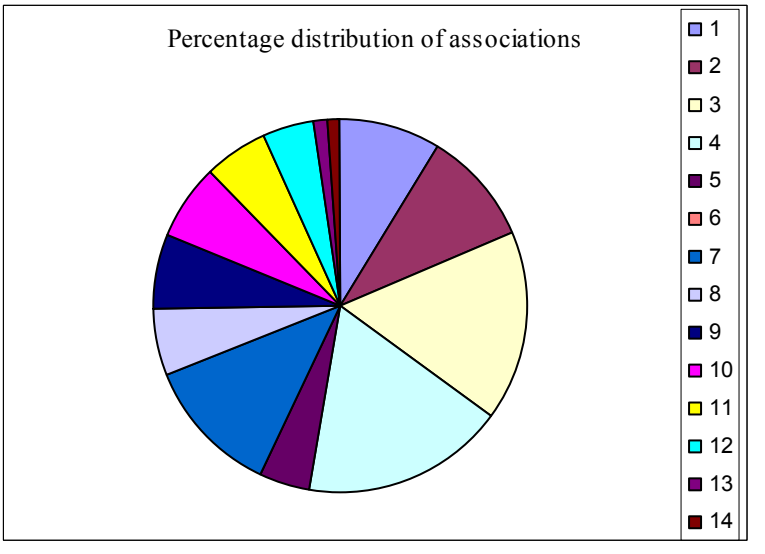

Fig 7. Percentage distribution of associations of 8th grade students (There no associations with genetics – No 6)

The word association test shows the different pictures of a human being of high school and middle school students. High school students value personal characteristics, moral aspects of human behavior, relation to and treatment of others. These characteristics of human beings are dominant in their associations. Second place occupy associations with the natural origin, dominated by living nature and sensibility of human beings, then follow associations with physiology and civilization aspects.

Middle school students remember better the physiological and anatomical aspects, followed by moral characteristics, individual development and natural origin. Those aspects predominate in the textbooks. They did not show any association with genetics. Comparison with high school students showed them an attainable perspective, awakened their need of competence and made learning goals personally relevant.

Content analysis, concept map construction and discussion

The concept map of the introductory lesson made by students in B3 and corrected by the teacher (Fig 2) and the discussion that followed (Table 3), directed them to the forthcoming studies, outlined the boundaries and limitations of the course and stressed the necessity to relate biology studies with those of other school subjects for better understanding of human beings.

The same was repeated with the second lesson, discussing the cell structure (Fig 3). It is a basic lesson in human biology. The map was constructed around the main cell characteristics – external appearance under a microscope, structure, cell division and cell differentiation. Definition was formulated as a generalization based on discussion. Working in groups of two was beneficial for developing students' abilities to interact and to pursue team goals (Swezey et al., 1994). Communication within the groups and in the class discussion was beneficial for overcoming the difficulties in studying abstract and complex science concepts. Integrating them into well structured cognitive

framework facilitated students' learning and improved their self-confidence (Schunk et al., 2008).

In the lesson "Human skeleton and the bones" 55 biological terms were counted. Students did their best to make a map (Fig 4). After making the first drafts some of them gathered and tried to overcome the difficulties and distinguish between essential and non-essential terms in studies, between main and subordinate knowledge. The preparatory work insured their competence in the classroom discussion, in making decisions and in correcting misunderstandings. They compared their concept maps and by reflection and self-reflection learned not only from the textbook and the teacher, but also from one another. Each concept on the map was explained by students' presentations. Misunderstandings were corrected by the teacher (Suret & McLaren, 2005). Some students used additional resources besides the textbook: atlases of the human body, internet images, models, etc. In the classroom discussion a plastic model of the human skeleton was used to help students get better impressions of the subject of study (Smith & Heise, 1992; DiCarlo, 2006).

Each student in B3 prepared a portfolio with the concept maps and used them in making a quick revision at the end of a given chapter (Table 4) and the school year. With each map they improved their skills for content analysis and concept construction. This gave them satisfaction and developed their self-esteem (Deci & Ryan, 1995; Novak & Govin, 1984). Students were motivated to learn by their success in learning. There were about 395 scientific concepts in the textbook, 5 new concepts per school learning period, which were not evenly distributed because of time allocated to practical work, revision, examination, project development, etc. Anatomical concepts predominated over those of physiology and hygiene. This ratio was not quite satisfactory.

Concept maps, used as demonstrations by the teacher gave students structured knowledge and a model of studying and memorizing (Suret &

McLaren, 2005). Some students in B2 decided to imitate the teacher and made concept maps while studying the lessons at home. The teacher's model maps attracted their attention, increased their curiosity, engaged them in active learning and stimulated their willful efforts in higher achievements (Graham, 1994). That explains the better results in B2 than in B1. In the latter students were given only a hint for the benefit from concept mapping. Very few students episodically tried concept mapping and seeing the difficulties easily gave up. That helped them understand the reasons for lack of persistence. The new method of learning in B3 challenged students, lifted the veil of monotony and lack of action and opened new horizons for intellectual development. Gradually the motivation from outside turned into motivation from inside as competence, positive thinking, enjoyment and self-confidence increased.

The behavior of the students in the classroom was significantly modified by the teaching methods (Table 5). What students did in class was considered valuable by many of them. Students liked to finish the school period with concrete visible products (Ormrod, 2003; Gilbert, 2002; Graham, 1994).

Table 5. Evaluation of students learning behavior in the classroom

Criteria	B1	B2	B3
1. Responsibility to learning tasks	3	4	5
2. Attention concentration	4	4	5
3. Activity	2	3	6
4. Persistence	2	4	5
5. Valuing of tasks	3	4	5
Mean	2.8	3.8	5.2

Skills in concept mapping developed gradually (Suret & McLaren, 2005). The difference in competency between B1 and B2 is higher than that between B2 and B3 (Table 6). Teacher's concept maps did make a difference

and challenged the students to successful learning. They were not only listening but also looking, thinking, connecting, comparing, asking questions, making notes and comprehending. The models set by the teacher were valuable and stimulating (Fig 8). Concept mapping proved to be a difficult endeavor and not accepted by everyone (McInerney, 2000). Most of the students were eager to start and do it, to be active in their learning process. They improved their reading and comprehension abilities and were fascinated preparing computer models. Self perception of ability worked as a strong intrinsic motivational force. Few others were not so eager and preferred the old way of learning.

Table 6. Evaluation of concept mapping skills as shown by the mean value

Level	Criteria /Mean value of each variable	B1	B2	B3
I	Core concept (concepts) correctly chosen	2.25	3.98	5.32
II	All concepts correctly underlined and included in the map	2.05	3.95	5.12
III	Concept hierarchy correct (1^{st}, 2^{nd}, 3^{rd} circle around the core)	1.85	3.86	4.45
IV	Connections correct (pointed by arrows)	1.60	3.79	4.40
V	Successive structure according to text correct (clockwise)	1.20	3.40	4.85
VI	Aesthetically visualized with illustrations	3.10	3.39	4.35
Mean		2.01	3.73	4.74

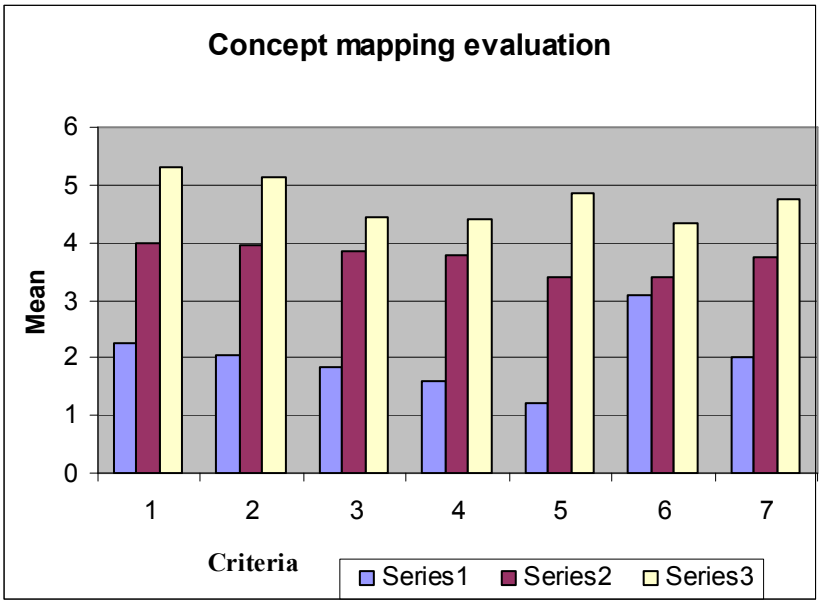

Fig 8. Graphical presentation of students mapping achievements: series 1 (B1), series 2 (b2), series 3 (B3); criterion 7 – mean value for each variable.

Results from achievement tests confirmed the results from observation and maps evaluation. First the psychometric characteristics of tests were assessed and inappropriate items rejected (Table 7). The difficulty of each item of the two tests was assessed. The range of difficulty is between 0.45 and 0.72, which means that the items of the pretest are with moderate difficulty, nearer to the range of the easy items. The same is true for the items of the posttest but they are less easy than those of the pretest (range between 0.50 and 0.62). Discrimination of pretest ranges between 0.35 and 0.50 (high discrimination, and of the post test it ranges between 0.40 and 0.65 (high discrimination). There are some items with moderate discriminative value. The pretest has high reliability, but the reliability of the posttest is questionable, near the high. The validity of both pretest and posttest is high which means that the two tests measure what they are intended to measure.

Table 7. Assessment of psychometric characteristics of tests

Reliability (R)		Validity (Vc)		Difficulty (P)		Discrimination (D)	
Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Post-test
0.85	0. 78	0.85	0.79	0.61	0.52	0.42	0.53

Concept maps improved achievement at the level of analysis and synthesis and at the level of evaluation, i.e. they stimulated the development of higher order thinking skills. Students could memorize using other learning skills, but discovering connections and cause and effect relationships was very well helped by mapping and discussion (Table 8, Fig 9).

Group work and discussions stimulated reflective self-awareness of each student and lifted performance at a higher level. Achieving educational goals satisfied learning motives (Fig 10).

Table 8. Means of achievement tests of the variables

Levels	Pretest			Posttest		
	B1	B2	B3	B1	B2	B3
Knowledge	3.60	3.46	3.55	4.50	5.40	5.60
Understanding	3.45	3.35	3.48	4.35	5.10	5.35
Application	3.29	3.25	3.15	4.28	4.85	5.15
Analysis	3.18	3.10	2.93	3.50	4.65	4.95
Synthesis	2.95	2.85	2.82	3.30	3.90	4.65
Evaluation	2.65	2.30	2.16	3.25	3.60	4.28
Mean	3.18	3.05	3.02	3.86	4.58	4.99

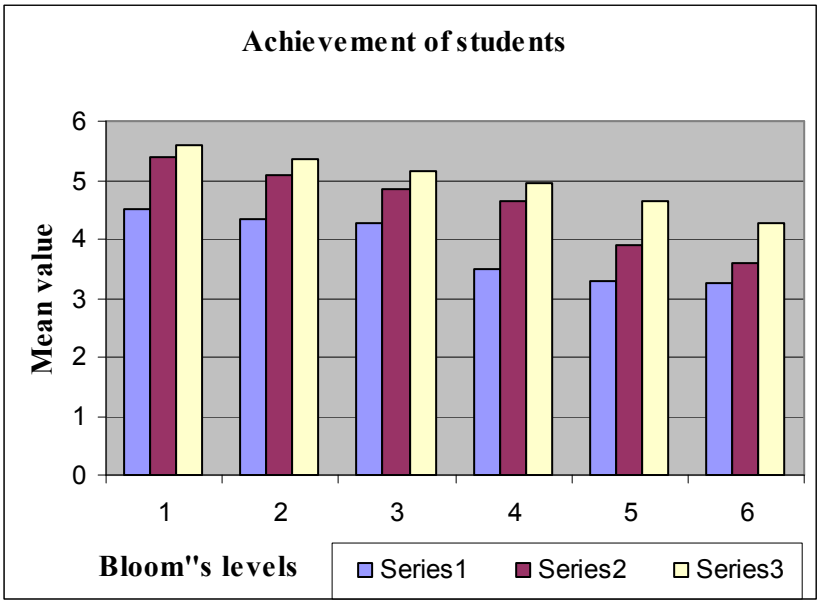

Fig 9. Levels of students' achievements: knowledge, understanding, application, analysis, synthesis, evaluation.

The successive use of word association test, content analysis, concept construction and discussion in the classroom ensured effective learning, motivated and stimulated students to enrich their spare time at home with meaningful work. Discussion and improvement of concept maps in the classroom helped students to correct their misunderstandings before they have memorized them as wrong (Table 9). Collaboration in team work was beneficial for drawing a clear picture and incorporating new knowledge.

Table 9. Comparative results from tests, observation and map evaluation

Variables	N	Pretest	Posttest	Observation	Map Evaluation	Mean
B1	20	3.18	3.86	2.8	2.01	2.89
B2	30	3.05	4.58	3.8	3.73	4.04
B3	30	3.02	4.99	5.2	4.74	4.98

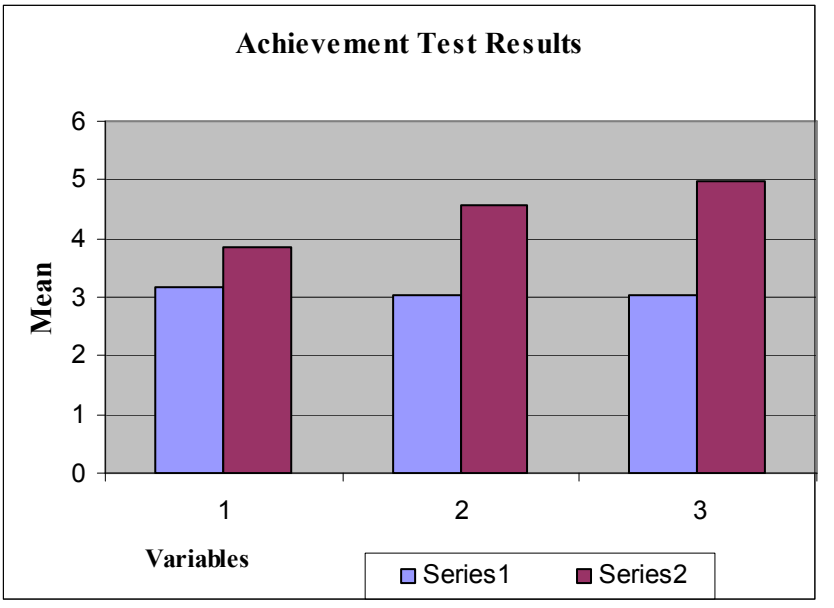

Fig 10. Graphical presentation of students' achievements: series 1 (Pretest), series 2 (Posttest) Variables: B1, B2, B3

Conclusions

The continuous word association test, combined with concept mapping and discussion, as applied in this study was successful in revealing the conceptual structures of 12th and 8th grade students to the stimulus words 'human being'. The concept maps were discussed with students in order to draw inferences about their knowledge and about the importance of the forthcoming studies in the new course Human biology in the 8th grade. The discussion awakened students' desire to learn more about themselves and other human beings. Such maps enhanced concept clarification and cognitive motivation. Although the response terms given by the participants varied at some aspects, areas of similarity emerged, and with little exceptions the criteria for the associations were covered. The target groups showed good informational orientation, concerning the stimulus word and responsibility in answering the test.

The investigation revealed the difference in the disposition of the target groups, the connection between concepts and feelings and the role of education in concept and intellectual development. Associative processes took place at different levels of learning. They were those processes that lead to the development and maintenance of cognitive connections (associations) between events, behaviors, feelings, thoughts, visual images, etc.

The word presented to the target people acted as a stimulus activating the memory and extracting the associated with it words which were on the top of their minds (Zaller, 1992). A dynamic associative structure was created in memory that involved representations of the words themselves as well as connections to other words. This structure of scientific terms played a crucial role in any task involving familiar words. Students could not create and retrieve representations involving familiar words, without relying on pre-existing associative structures created as a result of past experience. Thus the word association test was of benefit as a tool, used to reveal scientific conceptual structures.

Constructing concept (intellectual) maps systematically throughout the whole course of study in Human biology was a useful teaching and learning method for motivating, systematizing and organizing not only the concepts under study, but also the already learned concepts. It created a context for incorporation of new knowledge, for reconstruction of already acquired cognitive knowledge and experience (Bruner, 1960), and for building a new system of meanings of the studied object (Vigotsky, 1982-1984) as a conscious tendency to achievement.

There was a difference between the ways and the duration concept maps were used as study tools. Best achievement was accomplished in the variable (B3) in which students constructed concept maps throughout the school year. In doing that they acquired skills to study accurately, to think and rethink the studied information and to conceptualize it on a higher level (Mar-

zano, 1997). In the process of studying their attitude to learning changed and became more intellectually involving and satisfying (Field, 2005; Lehwald, 1991). The produced portfolio of concept maps of the studied topics on human biology was of great help to students in making a revision of the different chapters and the whole course. Thus the results of the word association test, content analysis and the concept mapping were used for constructing scientific knowledge and for learning associations in a conscious, intentional and effortful way (Wills, 2005). Concept mapping in each topic of human biology helped students brush up and organize their knowledge in a constructive hierarchical way (Smith & Heise, 1992; Swezey et al., 1994). This activity, done as homework, followed by discussion and elaboration in the classroom, directed students' behavior towards cognitive goals, increased effort and persistence in learning and improved their performance (Ormrod, 2003). Students not only learned the subject material, but they also learned how to learn. Active learning combined ability and effort and increased their efficacy (Bandura, 1986).

The good and structured representation of Human biology concepts in the teacher' concept maps in B2, attracted attention, directed students to cognitive goals and facilitated their learning. With the aid of the concept maps, associations were classified, structured, visualized and logical connections between them determined. A compact, wholesome and generalized picture of the key concepts was created, that facilitated learning, memorizing and remembering. The mind seeks clarity and completion and the map as a wholesome picture stimulated the "discovery" of new links between concepts, the generation of new ideas and enhanced its own improvement. Besides that, the association maps stimulated reflection and self-reflection and enhanced studies of the key concepts, using other sources besides the textbook.

Word association test motivated students in B1 too, but their motivation was not sustained after that and gradually faded. That brought us to the

conclusion that motivation should be constantly cared for and sustained in the classroom.

The methods – word association test, content analysis, concept map construction and discussion could be used successfully together in teaching, learning and evaluation in human biology education and in other school subjects. Applying them in school practice made students think of human biology as an interesting subject within their intellectual abilities.

This teaching strategy was very rewarding but it did consume much time and effort which students were not always able to spare. Science conceptual structures depend both on science education and culture of the community in which students grow and develop, including the climate and culture within the schools themselves. They are not the result of studying only one subject but integrate studies in all subjects with their everyday experience. Thus if successful learning strategy is employed in more than one branch of studies, achievements will greatly increase as well as self-regulation and self-control.

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APPENDIX A

Achievement Pretest (Examples)

1. Which cellular constituent is the carrier of heredity?
   a) ribosome
   b| cellular centre
   c) nucleus
   d) lysosome

For 2 and 3 correct can be one or more answers. Choose:
   a) 1, 2 and 3;
   b) 1 and 4
   c) 2 and 4
   d) All of the above are true

2. For ribosome is true:
   1) They are compact oval bodies
   2) They can be seen only with electron microscope
   3) They contain RNA and ribosome proteins
   4) They are organelles only of eukaryotic cells

3. For vitamin D is true:
   1) It is synthesized in the colon from bacteria
   2) It is synthesized in the skin in the presence of sunlight
   3) Its absence leads to damage of calcium and iron metabolism
   4) It is taken with food

4. Which connective tissue is characterized with deposition of calcium and phosphorous salts of large quantity?
   a) bone b) cartilaginous c) loose reticular d) compact reticular

5. Movable connection by means of joints is between the bones of:
   a) pelvis b) humerus and scapula c) ribs and breastbone d) the skull

6. In the process of growth the long bones loose:
   a) compact bone b) spongy bone c) yellow bone marrow d) red bone marrow

Correct answers: 1c, 2a, 3c, 4a, 5b, 6d

APPENDIX B

Achievement Posttest (Examples)

1. What is the name of the organ, taking part in the airways of the respiratory system and has three parts?
   a) Larynx b) Trachea c) Pharynx d) Epiglottis

For 2, 3, 4, 5 and 6 correct can be one or more answers. Choose:

a) 1, 2 and 3;
b) 1 and 3
c) 4
d) All of the above are true

2. Which is true for the chest?

1. It takes part in the ventilation of lungs
2. Its volume can increase and decrease
3. It protects the lungs and the other organs in the chest cavity
4. It is connected to nasal and mouth cavity and the larynx by means of three parts

3. For the alveoli it is not true:

1) They are made up of one layer of epithelial cells
2. They are the end parts of the bronchial tree
3. They are constituents of the lungs
4) Their total surface is about 200 m^2

4. Chemoreceptors taking part in breathing regulation are:

1) In close contact with blood
2) Sensitive to increased concentration of CO_2 in the blood
3) Sensitive to increased concentration of O_2 in the blood
4) Send impulses to the respiratory centre along nerves

5. The exchange of gases O_2 and CO_2 takes place in:

1. The tissues of the organism
2. The upper airways
3. Lungs
5. The lower airways

6. Direct and indirect effects of nicotine on the respiratory system are:

1. Accumulation of mucus and obstruction of bronchi
2. Inhibition of the movement of respiratory cilia
3. Repeated lung infections
4. Lung cancer

Correct answers: 1c, 2a, 3c, 4d, 5b, 6d

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THE INFLUENCE OF DISCIPLINES ON THE KNOWLEDGE OF SCIENCE: A STUDY OF THE NATURE OF SCIENCE

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Abstract. At least four factors affect pupils' understanding of the nature of science: teachers' specialization in different science areas (physics, chemistry, and biology), gender issues, teaching experience in elementary school environments, and the perspectives of acquiring necessary knowledge. This study is the introduction part of a research project which will be initiated soon. Four elementary science teachers participated in the study. The results reveal that participants' views of the aspects of nature of science are not solely diverged, based on their major disciplines, but there exist significant distinctions according to gender differences.

Keywords: nature of science, science education, teaching and learning

Introduction

According to science educators in public schools, particularly in the universities, the understanding of the Nature of Science (NOS) is extremely significant and crucial topic to be taught. The term "NOS" are going to be repeatedly used in the present study because this phrase cannot be avoided due to grammatical and linguistic considerations. Typically**,** the NOS refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992). Furthermore, the NOS is knowledge about how scientists use and develop scientific views: how they determine the question to investigate and how they collect data and analyze their findings from the observation of scientific facts about the world around us.

The preparation of scientifically literate students is a continuing goal of science education and current reforms in science education focus on the need for students to conceptually understand science rather than knowing a breadth of scientific facts (AAAS, 1993). For instance, National Research Council has focused on this goal in their national reforms (NRC, 1996). Since the NOS is an essential topic for the students, it requires further investigation in different perspectives. In this current study, it is hypothesized that if their knowledge of the NOS are increased, in-service elementary science teachers can improve their confidence and abilities to effectively deliver science instruction at the level of national reforms.

There have been many disagreements about the true definition or meaning of the NOS among philosophers, historians, and science educators.

In general, science educators typically define the NOS as the epitemology of science, science as a way of knowing, of the values of beliefs inherent to the development of scintific knowledge. However, historians and philosophers of science do not agree with this scientific definitions because

they find it too general. The issue of the existence of an objective reality as compared to phenomenal realties is a case in point.

More specifically, those disagreements have been discussed by Lederman & Abd-El-Khalick (2002), but they claimed many of the disputed issues as irrelevant to K-12 instruction. Also, they suggested that there is an acceptable level of generality regarding the NOS that can be made accessible to K-12 students and relevant to their daily lives.

Among the characteristics of the scientific enterprise corresponding to this level of generality are the following aspects: that scientific knowledge is tentative (subject to change); empirically based (based on and/or derived from observation of natural world); subjective (theory-laden), necessarily involves human inference, imagination; and creativity (involves the invention of explanations); and is socially and culturally embedded (Lederman, 1992).

Two additional aspects are the distinction between observations and inferences, and the functions of, and relationships between scientific theories and laws. Those aspects of the NOS are generally adopted by teacher educators in science and they will be emphasized in the present study. There have been some enhanced investigations that have examined how pre-service teachers could increase their conception of the NOS. Among those, many studies have been conducted about teacher preparation programs (Akindehin, 1988; Ogunniyi, 1983). As a result, these researchers have suggested two distinctive approaches: *the explicit approach,* which basically makes use of the relationships between the philosophy of science and the instruction of the NOS to improve pre-service or in-service science teachers' conceptions.

In contrast, as a second type of approach, *implicit approach* does not make use of specific attention to the NOS and implicit messages are exemplified. However, this approach assumes that every necessary knowledge of the NOS is acquired during the learning process natuarally without any explicit effort. On the other hand, there have been several studies which aimed

at in-service teachers instead of pre-service teachers. Such as, Lederman (1992) claimed that research regarding improving in-service elementary science teachers' conceptions of the NOS was influenced by two assumptions. Firstly, teachers' conceptions of the NOS directly affect their classroom practices. Secondly, teachers' conceptions of the NOS have a cognitive impact on students' conceptions. Although Lederman (1992) made this assertion, he did not explicitly test these two assumptions. Then these assumptions were later explored in classroom science, the research that resulted from testing the first assumption showed that the relationship between teachers' conceptions of the NOS and their classroom practice was more complicated than they originally assumed. Based on the previous research conducted on pre-service or in-service teachers' understanding the NOS, it is clear that teachers definitely cannot teach what they do not understand (Akindehin, 1988).

In order to be able to instruct the NOS to their students, teachers should possess adequate knowledge of scientific enterprise. Studies on the conveying of teachers' conceptions into classroom practices mainly support the idea that, even though teachers' conceptions of the NOS can be considered as an important condition, these conceptions are not sufficient (Lederman, 1992). It has been shown that elementary pre-service science teachers do not generally have acceptable conceptions of the NOS (e.g., Lederman, 1992). Even those interventions attempting to teach the NOS have proven difficult and did not sufficiently help pre-service teachers learn and retain appropriate conceptions (Akerson et al., 2000). The prospective or present science teachers' incomplete, flawed, and non-efficient understanding of the concepts of the NOS is an unfortunate problem that, in turn, leaves our children as scientific illiterate individuals. Thus, some improvements or solutions will be suggested here and then they must be considered for applying to the science teacher preparation programs to prevail over this vital problem.

Schwartz & Lederman (2002) conducted a case study of two science

teachers in terms of how they learn and address the NOS in their classroom. It was one of the recent studies, and an influential one, that had been done with only two science teachers selected from the group of participants because of their different levels of the NOS understanding and difference science background knowledge and science teaching experience. First, the participants participated in series of activities, embedded in specific subject matter in nature, to teach about aspects of the NOS. Then, they joined in a science research internship associated with NOS instruction. Next, they were observed while they were teaching science in their science classroom environments. The researchers, afterward, collected the participants' NOS knowledge, instructional plans through questionnaire, interviews, lesson plans, and classroom observations. In conclusion, they recommended that there should be some interaction between science educators (as researchers) and participants in order to increase the longevity of teaching the aspects of the NOS in teacher education programs. Because with the help of NOS courses and faculty members' continous effort to include the aspects of the NOS (implicitily or explicitly) can help students to retain the NOS.

Physics educators and major science education organizations are increasingly supporting the preparation of scientifically literate students (e.g., AAAS, 1993). In 1996, National Research Council (1996) expressed that the goal of national science education standards is to "create a vision for the scientifically literate person and … and will serve to guide the science education system toward its goal of scientifically literate citizenry in productive and socially responsible ways". In spite of that, scientifically literate citizen is supposed to possess knowledge of scientific theory, laws, principle, concept, technology and relationship to society. Moreover, this person should reveal the understanding of the NOS.

Finally, according to Gerald Holton (DeBoer, 1991) a scientifically literate person is described as having two facets which are: "(1) some content

understanding-knowing and keeping up with at least one chosen, even though small, part of science, and (2) some understanding of application-trying to keep in touch with a variety of other scientific developments."

According to Lederman's (1992) review of literature of research on the NOS, various different groups of students, especially high school students, have been studied regarding their conceptions and understanding of the NOS almost every year since 1960. Yet, the results of these fifty years of investigations advocated the idea that science teachers do not possess adequate conceptions of the NOS and irrespective of the instrument used to assess understanding (Lederman, 1992). Although science teachers are provided with the detail instructions of curriculum, they often do not posses adequate knowledge and understanding of the NOS. Therefore, the study of pre-service and in-service teachers have been drawn more attention.

Kleinman (1965) conducted a study of teachers' questioning. He observed elementary science teachers three times each week during a semester. He concluded that when student ability was held constant, it was noted that teachers who asked more critical thinking questions impart a better understanding of the NOS to both Grade 7 and Grade 8 males and females than teachers who asked fewer questions of this type.

In a similar study, Behnke (1961) focused on the comparing 200 biology teachers and 421 physical science teachers' understanding of the NOS, science and society, scientist and society, and the teaching of science. He found no significant difference between those two groups of teachers.

Billeh & Hasan (1975) investigated whether those factors cause any increase in the teachers' understanding of the NOS by science 186 secondary teachers in Jordan. The teachers were included from various disciplines: physics, biology, chemistry, and physical science. They used the Nature of Science Test (NOST) to assess understanding of the NOS. Discenna & Howse[1)] assessed a research on the NOS at the elementary level in the 1990s.

They analyzed reflection essays of twenty-two American pre-service elementary science teachers, which took place throughout 15 weeks of biology or physics course. They investigated problem solving and inquiry-based activities and concluded that these views of science were not changed during the semester.

Overall, importance of investigating the aspects of and more importantly adequate knowledge of them have been proven an important research area since mid 20th century. The term "scientific literacy" was born because of the NOS. Even though conception of the NOS was studied for a long time, still, it is necessary to investigate from different perspective as Schwartz & Lederman (2002) suggested NOS aspects should be learned starting in elementary school environment therefore prospective science teachers should possess adequate knowledge of the NOS. Recent NOS studies invetigates both pre-service and in-service teachers' understanding of the NOS aspects and seek possibles solutions to increase the knowledge. This study serves for this purpose as one of its goals.

Purpose of the study

The purpose of this study is to investigate the extent of science teachers' understanding of NOS. It will also compare this knowledge with the length of their science teaching experience and the braches of science they studied in teacher preparation colleges, e.g. physics, chemistry, or biology.

Describing how experienced teachers' knowledge of the NOS will help to reform instruction and that will provide examples for use in the science methods courses taught in science teacher preparation programs. It is essential to investigate whether teachers improve their knowledge of the NOS at the end of their college education.

This is important because many science teachers do not know as much as they should about the NOS to become effective science teachers. For this

reason, educators and faculty members have to find possible solutions to get to the bottom of this problem in teacher preparation institutions. If the science teachers' knowledge and understanding of the NOS is not at the desired level, then the teacher preparation programs should be looked over and must, if necessary, be revised accordingly to resolve the deficiencies of pre-service science teachers.

Specifically, the present study seeks to investigate and propose possible solutions to improve science teachers' knowledge of NOS. The research questions that will guide the present study are: (1) what are the key factors that cause conceptions of the NOS among elementary science teachers at an US elementary school in the Midwest who specialize in diverse science areas; (2) what is the relationship between the length of their teaching experience and their understanding of NOS among elementary science teachers.

Participants

This study was purposefully designed as a small part of a big research and the data collection of the second part is still continuing. It was conducted in a Midwestern Public School District with four primary elementary science teachers. The participants selected for the study were selected through a careful consideration among the elementary science teachers in the district. In the selection process, we purposefully decided to have science teachers with different disciplines and also different genders for the sake of the research questions. Specifically, four specific criteria, adapted from the participant selection process of Akerson et al. (2000), were as follows: (1) two groups of sample that consists of two women science teachers and two men science teachers; (2) one of the participants in each gender group should be at least five years or more teaching experience in his or her discipline in the same district; (3) science was taught as a separate subject; and (4) teachers hold as

least a bachelor degree in science.

Pseudonym is used in order not to reveal the identities of teacher participants. Four in-service elementary science teachers, two females and two males, participated in the study. Harry and Alex were male participants with Harry holding a bachelor of physics degree with two years teaching experience in science and Alex holding a bachelor of chemistry degree with five years teaching experience. Kim and Berry were female participants and Kim had a bachelor degree in biology with 30 years teaching experience. Berry holds a Bachelor degree in Physics with two years teaching experience. The reason for selecting both types of gender was to compare the differences of each gender's conceptual understanding of the Nature of Science. Similarly, it is also desired to identify teachers' conceptualizations of the concepts of NOS in relationship with length of their teaching experience and specialization of different disciplines.

Data collection

Main data source of the current study was teacher interviews. All four interviews were carried out in the school where the participants were teaching at the time of study. Each interview took place approximately one hour which included semi-structured set of interview questions. Interview questions consist of both multiple choice and open-ended items with follow-up discussion questions. All interviews were audio taped and transcribed for analysis by the authors later.

Teacher interview protocol was developed among three different NOS questionnaires. Particularly, an analysis of three different types of interviews questions used as a research instrument in the questionnaire were as follows: (1) Nature of Science Survey (NOSS) questions which was first proposed by Kimball (1967); (2) Nature of Science Test (NOST) which was suggested by Billeh & Hasan (1975); (3) Views of Nature of Science- Elementary School

version (VNOS-E) by Lederman et al. (2001) questions were administered one time during the academic school year.

Sample questions of NOSS and NOST and full version of VNOS-E are included in appendix section (Appendix). Full version of NOSS and NOST can be found in above original papers of Kimball (1967) and Billeh & Hasan (1975).

Results and discussion

Table 1. *Analysis of the aspects of NOS among the elementary school teachers participated in the study*

NOS aspect	Harry	Alex	Kim	Berry
tentativeness	+++	++	++	+++
creativity	++-	++	+	++-
emperical	++	+-	+	++
observation	++	+	+	++-

\+ :provide a definition or affirmative response
++ :provide a description in own words, examples from class
+++ :provide a description in own words and additional supporting examples
\- :inconsistent statement or inappropriate example given

Table 1 indicates the findings obtained from VNOS-E survey questions and presents the results of the five aspects of NOS through two NOS assessments (VNOS-E, interviews) administered during academic semester. Data analysis resulted in rich understanding of aspects of the NOS for both Harry and Berry. On the other hand, it showed that both Alex and Kim possess inadequate of understanding aspects of the NOS. The results of data analysis for all participants are discussed separately later.

Both Harry and Berry presented an outstanding understanding of the NOS aspects. Especially, at the aspects of tentativeness and subjectivity that are two most important aspects, their understanding exceeds average level because they defined tentativeness as dynamic property of science and subjectivity as science is affected by scientists' own opinion. Above

descriptions are almost the same descriptions of tentativeness and subjectivity of science as scientifically. They also provided various examples from their teaching and research experiences for example scientific advances lead to technological advances and new technology assists scientific advances. However, they didn't possess same degree of knowledge of the aspects of creativity, empirical, observation/inference. For example, they didn't claim that creativity as well as observation didn't play an important role in the progress of science, which opposes teru scientific explanations. In conclusion, their overall understanding of the seven aspects of the NOS was intermediate but satisfied the desired levels.

Participant science teachers' responses in Table 1 also pointed out that although two of them, Alex and Kim, didn't possess expected degrees of knowledge (which is: +++), they indicated based knowledge and understanding aspects of the NOS with only providing adequate definitions. In addition, according to table1, all of them indicated they have satisfactory understanding and knowledge of the NOS. On the other hand, on some aspects, tentativeness andsubjectivity, Harry and Alex excelled and showed knowledge and understanding of the NOS above average level. The reason for why they achieved this level may be related to which disciplines (both physics) they mostly studied in college because students of physics usually show high degree of analytical thinking than other students. Scientific reasoning reflects one's knowledge and understanding of the NOS properties at some level intentionally or unintentionally. Finally, with this finding it can be stated that at some level, length of teaching experience affect knowledge of the NOS at some degree because Berry has 30 years of teaching experience and Harry has only two.

The first major finding in the study was that science teaching experience was not importantly related to teachers' understanding of science based on the NOST (Nature of Science Test). That was actually one of the

claimed hypotheses at the beginning. It stated that the more elementary teacher holds teaching experience, the less they possess understanding of the NOS concepts. This finding cannot be generalized because of the sample size in the current study. However, the conclusion had agreement with the findings of the studies (Billeh & Hasan (1975); Kimball (1967); Lavach (1969)), where quantitative and statistical studies were conducted to investigate elementary in-service science teachers' conceptual understanding of the NOS.

A second major outcome was identified as academic status and teaching experience of participants' disciplines (physics, chemistry, and biology) were related with each other according to their scores on the NOST. It is also shown that they shared similar results in terms of the university graduation, educational qualification, teaching experience and previous in-service teaching. Taking these facts into account, it is claimed that there were no significant relations between teachers' gain scores on NOST and their educational qualification according to the current study. Also, this finding was consistent with Billeh & Hasan's study (1975). Therefore, it is convenient, regarding findings of this study, to state that the pre-service training had been equally effective with both groups of science teachers.

Another finding of this study was that the teachers' scores of NOST questions are significantly related to the subject they teach. Hence, it can be concluded, without generalizing, that no differences in concepts can be found corresponding to the science disciplines they studied in college. This finding had agreement with the conclusion of Behnke's study (1961).

According to NOSS (Nature of Science Survey), it was discovered that almost all of participants have shown understanding of what a scientific theory is, what the difference between scientific theory and law is, except the 30 years experienced teacher, Kim. This finding may imply that science teachers start to forget major concepts of NOS as they teach science without including the NOS aspects in their teaching plans as time passes. This

apparent lack of change in understanding of the NOS with time and experience is the same findings as Kimball (1967) found in his study. Indeed, this participant did even described what a law or theory means:

> "Yes. I think there is a difference between theory and law. However, honestly I do not know difference now. As far as I know, theory is a frame for certain phenomena. Law is just one of the rules in this frame." (Her answer to question #3 in NOSS: Is there a difference between scientific law and theory?)

In other words, this participant seemed to believe that theory is more structured than law and this is not expected from an experienced science teacher. Moreover, half of the participants showed that they truly knew tentativeness aspect of the NOS. Especially Berry seemed to have a good understanding of it:

> "Theories do change only laws don't change. You only can find the laws through theories. They are scientific steps… That is how they find the scientific laws." (NOSS question #1)

Another interviewee, Harry, noted that "Yes, they (theories) do change… Scientists keep adding to the theories so that they become better as discoveries are made" (Harry, NOSS #1). Nevertheless, as evident in this quotations, most participants believed that some theories will eventually be proven and change into laws, in which case they are not liable to change. This result is nonetheless consistent with previous research (Behnke, 1961).

Consistent with research in science teachers' views of the NOS (e.g., Aguirere et al, 1990; Carey & Stauss, 1968), participanting science teachers held naïve views of many of the investigated aspects of the NOS at the end of the study. However, as indicated in table 1, Harry and Berry did prove some

new findings of the NOS concepts learning because they possess high level of knowledge of tentativeness and subjectivity of the NOS. Overall, they showed that science teachers are able to learn NOS concepts if they are prepared adequate in teacher preparation programs.

Participants' views also lacked consistency; features which were expected given the teachers are often not provided with opportunities to reflect on and clarify their views of the NOS (Abd-El-Khalick, 1998). Moreover, the participants' views of the target aspects of the NOS were not significantly different. For the cases of Alex and Kim, they showed similar understandings of the NOS aspects. They did possess adquate knowledge of tentativeness and creattive aspects of the NOS but they didn't have enough understanding of empirical and observational aspects.

If we evaluate them individually, Harry demonstrated that he helda high interest but some naïve views of the NOS concepts. On the other hand, Berry showed similar pattern but with appropiate examples which is used to describe aspects. Alex showed low interest, many irrelavant views and largely very low level of understanding of the NOS with no examples. Similarly, Kim had a low interest, invalid views, some weakness and confusion. She wasn't able to elaborate and explain aspects of the NOS based on her background knowledge and experience, either.

The results of this study were nevertheless compatible with previous studies conducted on alternative conceptions (Akerson et al, 2000) and promoted to illustrate the cohesive conceptions with which learners persist their own views. Nevertheless, participants' views of NOS have been constructed over years of elementary education and teaching experience they have gathered while teaching science. It is unlikely that elementary science teachers would achieve true knowledge and understanding of the NOS in the process of teaching or college education unless it is offered in an elementary science method course in the teacher preparation program. However, investing

more time to concentrate on the NOS in method courses may not be realistic. This is particularly so unfeasible that there are only few science method courses in teacher preparation program. Consequently, in order to improve science teachers understanding of NOS, it is strongly recommended that the number of hours dedicated to it, in the science method course in science teacher preparation programs, should be increased.

In addition to that recommendation, there is another approach, which can be carried out in the science method courses. Participants in the current study were not informed about inadequacies of their views of the NOS. They were not offered any NOS instruction materials, either. In other words, they did not experience any cognitive dissonance regarding their NOS views, and so correcting their misconceptions of the NOS might be easily accomplished.

Therefore, when conducting a study on science teachers' conceptions of the NOS, it would be very constructive to set up NOS instruction during investigation and devote it mostly to conceptual changing from misconceptions of NOS the participants possess.

Thus, explicit reflective instruction about NOS integrated within a complete conceptual change approach (Hewson & Hewson, 1983) might be very effective and a useful tool to enhance pre-service elementary teachers' NOS views.

As a final remark, findings of this study strongly disagree with the idea of overstressing the NOS instruction, best undertaken in the teacher preparation institutions. On the other hand, the NOS instruction is not covered by the curricula of the traditional science content courses offered at these institutions. Reforms in science education agenda at the college level seminar course seems to be capable of enhancing future science instructors' views of the NOS, teaching in both elementary and secondary level classrooms. Consequently, aspects of the NOS should be emphasized both NOS courses and other science courses such as freshman physics, chemistry, and biology in

college in order to overview them at the beginning of the semesters. By achieving that, pre-service science teacher will be able to retain any knowledge they learned in college so will be ready for teaching science courses afterwards. In the same token, at elementary and secondary schools, it is suggested that every science teacher should spend at least a week to go over the NOS aspects and review them to remind himself/herself and students what it is. We could achive our ultimate goal of creating science literate individuals in all nations.

APPENDIX

Sample NOST items (Kimball, 1967)

Scientists use classifications in science to:

(a) explain scientific observations.
(b) organize scientific observations.
(c) predict scientific observations.
(d) favor scientific observations.

Which statement best describes scientific models?

(a) models faithfully describe and represent natural phenomena.
(b) models illustrate relations among phenomena.
(c) models simplify natural phenomena.
(d) models represent patterns of relations inherent in nature.

Sample NOSS items (Billeh & Hasan, 1974)

1. After scientists have developed a theory (e.g., atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to teach scientific theories. Defend your answer with examples.

2. Is there a difference between scientific law and scientific theory? Explain.

Views of Nature of Science Elementary School Version (VNOS-E) items
(Lederman et al., 2001)

1. What is science?
2. (a) What are some of the other subjects you are learning?
   (b) How is science different from these other subjects?
3. Scientists are always trying to learn more about our world. Do you think what scientists know will change in the future?
4. (a) How do scientists know that dinosaurs once lived on the earth?
   (b) How sure are scientists about the way dinosaurs looked? Why?
5. A long time ago all the dinosaurs died. Scientists have different ideas about why and how they died. If scientists all have the same facts about dinosaurs, then why do you think they disagree about this
6. TV weather people show pictures of how they think the weather will be for the next day. They use lots of scientific facts to help them make these pictures. How sure do you think the weather people are about these pictures? Why?
7. (a) Do you think scientists use their imaginations when they do their work?
Yes No
(b) If **No**, explain why?
(c) If **Yes**, then when do you think they use their imaginations?

NOTES

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НАНОНАУКА И НАНОТЕХНОЛОГИИ: ФИЛОСОФСКИ И ОБРАЗОВАТЕЛНИ ПРОЕКЦИИ – ИЗБРАНА БИБЛИОГРАФИЯ ЗА УЧИТЕЛИ

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Резюме. Нанонауката е между най-бързо развиващите се научни области. Учениците в средните училища не получават представа за нея. От една страна това е правилно, защото в средните училища се изучават утвърдени и достоверни факти и теории, чрез които учениците ще оформят своите представи за света, в който живеят. Новите развития в науката, обаче, ангажират вниманието на учениците и могат да стимулират интереса им към природните науки. Затова такива теми могат да бъдат разисквани в проектното обучение и/или в извънкласните учебни форми. Развитието на нанотехнологиите поражда редица въпроси от философско, етично и социално естество, за които учителите би трябвало да имат някаква представа. Статията предлага избрана библиография по тези въпроси – цитираните литературни източници могат да формират адекватно отношение на учители и ученици към тези сложни въпроси на модерната наука.

Keywords: nanoscience, nanotechnology, philosophical, ethical, social, educational

Нанонаука

Нанонауката изследва обекти, чийто линейни размери са малки на микроскопската скала от разстояния. Историческите корени на науката би трябвало да се потърсят в развитието на европейската колоидна химия от началото на XX век. Колоидната химия е наука за диспергираното вещество (Evans & Wennerstrom, 1999). Размерът на частиците в такива системи е между 1 и 100 nm. При такива размери на наноскалата (Baird et al., 2004) веществото губи много от свойствата на обемните фази. Това е свързано с обстоятелството, че размерите на частиците, ако не в трите направления, поне в едно от тях, стават съизмерими или по-малки от радиусите на корелация на някакво физическо или химическо свойство (дължината на свободния пробег, размерът на зародиша на новата фаза и пр.) и това се отразява в чувствителност на обекта от неговия размер. Разбира се, има разлика между състояние и структура. Състоянието на системата следва термодинамичния формализъм, който може да бъде преформулиран с отчитане на ефектите на размерността (например с представата за *разклинящо налягане)*. Действието на далечните сили на взаимодействие в междуфазовите контактни зони може да се манифестира с термодинамичните величини *линейно напрежение* и *точков омега-потенциал*. Към условията за механично равновесие в такива сложни капилярни системи трябва да се добавят и условията за устойчивост на тези равновесия. Нанообектите дори при едно състояние, например квазитечно, могат да се проявяват в различни структури. Тук разнообразието е много голямо и то дава възможност за различни, често неочаквани, технически, медицински и други приложения. Бързото развитие на наннауката в последното десетилетие в голяма степен се дължи на този факт.

Философски, социални, етични и образователни аспекти на науката

Нанонауката дава обилна храна за общи философски разсъждения (Baird et al., 2004). Известно е, че две двумерни фази не могат да съсъществуват в равновесие (Ландау & Лифшиц, 1976; Toshev, 1995). Вече е поставен въпросът дали тримерният свят не е интерфейс на съсъществуващи фази с по-висока размерност (Zwiebach, 2004). Тогава дали нанообектите не са врата към светове с размерност, различна от три. Такъв род въпроси могат да доведат до изграждане на нова научна парадигма, която да осигури развитието на нова „нормална" наука по терминологията на Kuhn (1962) или на твърдо ядро на нова изследователска програма по терминологията на Lakatos (1970). На тази основа може да се изгради и ново отношение към религията, различно от утвърдения в нашата страна и училище примитивен атеизъм, характерен за комунистическите режими.

Впрочем противопоставянето на науката и религията в училището и обществото е неправомерно от най-общи съображения. Докато науката се занимава единствено с *възпроизводимите факти* и нейн основен белег е *доказателствеността,* то светът на религиите (вярата) се изгражда аксиоматично чрез твърдения, които се приемат безусловно и без доказателства и човек е готов на това, защото вярата го дарява с морал. Следователно науката и религията нямат допирни точки, за да бъдат сравнявани и евентуално противопоставяни. Осъзнаването на тези особености трябва за започне още в училище, но затова са нужни подготвени учители (Reiss, 2009; Glennan, 2009; Brook, 2010).

Нанонауката има и своите социални измерения, които също не са обект на достатъчно внимание досега (Sweeney et al., 2003). Преди всичко това е идентификацията на етичните и социалните проблеми, породени от сегашното и бъдещото развитие на нанотехнологиите, както

и проблемите за законовото регулиране на това развитие (Fielder & Reynolds, 1994). Дали всичко, което се прави в лабораториите в дългосрочен план ще бъде от полза за обществото? (Weckert, 2001).

Такъв род въпроси имат и своите образователни измерения – новите поколения изследователи имат нужда от по-обща образователна парадигма (Entwistle, 1990), която да се гради чрез амалгамата на 'твърдата' [hard] и 'меката' [soft] наука (Toshev, 2006). Построяването на този нов образователен модел предполага ред от последователни действия (multi-tired approach (Schummer, 2004), които включват както таксономията на термините, така и основните образователни стратегии, преди всичко *конструктивизмът* (Gale & Steffe, 1995) и техниките за повишаване ефективността на обучението (Entwistle, 1990). Въпросът за таксономията на термините, т.е. за езика на обществените науки, никак не е за подценяване, особено в нашата страна, защото „Different social realities provide different experiences. They lead to different ways of seeing the world and consequently lead to different beliefs concerning our apprehension of the world" (Markova, 1982).

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NANOSCIENCE AND NANOTECHNOGIES: PHILOSOPHICAL AND EDUCATIONAL DIMENSIONS – SELECTED BIBLIOGRAPHY FOR SCIENCE TEACHERS

Abstract. Nanoscience is among the fastest growing academic fields. Pupils in secondary school do not get an idea of it. Certainly it is correct because secondary schools are taught by established and reliable facts and theories through which students will form their ideas about the world where they live. However, new developments in science engage students' attention and may stimulate interest in science. That's why such topics may be discussed when training students by projects and/or in extracurricular school

forms. Development of nanotechnology raises many philosophical questions, ethical and social issues for which teachers should have some idea. The article provides a selective bibliography on these issues – listed literature could facilitate teachers in shaping their opinion about these complex questions of the modern science.

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● ***Personalities in Science and Education*** ●

АЛЕКСЕЙ ШЕЛУДКО (1920-1995): БИБЛИОГРАФИЯ

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Резюме. Статията предлага пълна библиография на научните публикации на проф. дхн Алексей Димитров Шелудко (1920-1995), б. ръководител на Катедрата по физикохимия на Софийския университет „Св. Климент Охридски”, действителен член на Българската академия на науките и на Общогерманската академия „Леополдина”, световно известен учен, основоположник на българската научна школа в областта на колоидната наука.

Keywords: colloid science, interfaces, thin liquid films, disperse systems, phase formation, Scheludko

Семейна среда

Алексей Димитров Шелудко е роден на 18 май 1920 г. в гр. Хале, Германия. Баща му, Дмитрий Илич Шелудко (1892-1963) е украинец, филолог, владеел писмено и говоримо 14 езика, специалист по трубадурите и минезингерите, познавач на големия френски поет

Мистрал. Впечатляващо е, че трудовете на този доцент по филология в Кьолн продължават да се цитират в научната литература до днес.[1)]

Майката на Алексей Шелудко - Нора е родена в Сливен и е дъщеря на руски евреин – емигрант. Тя е следвала в Швейцария музика и славянска филология и по последната специалност се е дипломирала в Софийския университет. Между публикациите на Нора Шелудко има една[1)] с ценни сведения за баща й – д-р Йоаким Транен (1859-1927). Дъщеря на д-р Транен е д-р Валентина Транен (1897-1990) – първата жена-хирург в България, била е началник на хирургичското отделение в Плевенската болница (1930-1932). По-късно д-р Тренен се е преместила в София, където е имала частна хирургическа клиника. Д-р Тренен живееше на ул. „Хан Аспарух” в София и професор Шелудко хранеше топли чувства към леля си.

Дмитрий Шелудко със семейството си е трябвало да напусне Германия като в България е сменил и научната си тематика. Тук той е познат като специалист върху българското възраждане, украинската литература и Тарас Шевченко.

Вместо предисловие

Тук е представено интервю с професор Шелудко,[3)] за което няма сведения, че някога е било публикувано. Остава неизвестно кой е задавал въпросите, чиито отговори ще прочетете по-долу. Във всеки случай този текст наистина е добър увод към списъка на публикациите на проф. Шелудко, защото той по автентичен начин разкрива ясно и ярко личността на автора си.

А. Шелудко (1920-1995)

Защо предпочетохте химията? Каква роля играе дарбата в научното творчество?

Физиката винаги ми се е струвала най-интересната наука, защото тя е в основите на естествознанието. Следвах въпреки това химия, защото по онова време работа в лаборатории за физици нямаше. Във физикохимията намерих поле за приложение на добитите химически знания в съчетание с интересите ми към физиката.

Успехът в научното дирене се определя от много фактори: от интересите на изследователя и неговата работоспособност, от

обективните и субективните възможности за разрешаването на даден проблем, от това дали е избран перспективен проблем и подходящ път за решаването му, от това дали някой друг няма да получи преднина в научното състезание. Кое от тези и други обстоятелства влиза в състава на понятието дарба за мен е въпрос, който остава неизяснен.

Има ли днес място за значителни научни открития? Има ли големи открития и откриватели в областта, където работите?

Не ми изглежда вярно мнението, че големите открития в науката вече са направени и остава да се доработват детайли. Науката в своето развитие разкрива все нови проблеми и представя нови методи за тяхното разрешаване. Факт е, че сравнително неотдавна, Айнщайн основно преобразува с необозрими перспективи една от най-завършените науки – механиката. Днешният напредък в биологията също е фундаментален. Днешното състояние на науката се характеризира с все по-голямата трудност да се припише дадено откритие на даден автор. Толкова е нарастнал броят на работещите в полето на науката и темпът на нейното развитие, че новите резултати обикновено се получават в различни варианти едновременно на много места, като всяка отделна по-значителна работа се оказва вплетена в общия поток. Все пак днес все още се появяват обединяващи школи, личности и отделни научни постижения. В най-близката до мен област такива изпъкващи личности са например Б.В. Дерягин в СССР – физикохимия на повърхностите и нашият забележителен съотечественик Р. Каишев – кристали и кристален растеж.

За съжаление не съм в състояние да дам съвет как се правят значителни научни открития. Ако това ми беше известно, сам щях да се възползвам от него. Въобще тайната на научното творчество си остава засега тайна, в която науката още не е проникнала. Говори се напоследък

за необходимостта, па дори се и планира създаването на наука за развитието на науката. Какво ще излезе от тези проекти ще покаже бъдещето. Засега остава да се препоръчат блестящите фейлетони на Карел Чапек за това как се прави вестник, филм и театрално представление.

Как предпочитате да работите – сам или в колектив?

Много по-леко и приятно се работи в колектив. Впрочем понятието колективна работа в науката е по-сложно. То обхваща не само непосредственото сътрудничество и дори експлотацията на колеги, но и това да си на ръба между познатото и новото и да търсиш последното заедно с други учени, па макар те да работят на хиляди километри далеч. Такова другарство в научното дирене е характерна особеност на всички области на науката и неговата интензивност е признак за това, че даденият проблем се развива успешно и е наистина актуален и перспективен. Аз съм щастлив, че непосредствено сътруднича в колектив от талантливи и ентусиазирани колеги и че съм в тясна връзка с редица забележителни учени, пръснати по цял свят. Този колектив е неоценима подкрепа и източник на сигурност в работата.

Какво ще кажете зе проблема „бащи и деца" в науката?

Този проблем винаги е съществувал и ще съществува докато светът се развива и децата растат при условия, различни от тези при които са се оформяли бащите. И колкото темповете на развитие са по-бързи, толкова по-голяма е разликата в светогледа и възможностите между поколенията. В науката този проблем е много остър и при днешното състояние на устремно развитие особено подчертано изпъква. Днес, повече отколкото в миналото, напредъкът в науката изпреварва възможностите на учения да се подържа на ниво през целия си творчески

живот. Това особено се проявява във възможностите за използване на нови методи, нови подходи и в частност на нов математичен апарат. Стремежът на някои учени да запазят на всяка цена ръководната си роля и функции ги превръща в спирачка за развитието на науката. Трябва да се разбере навреме обективното състояние на нещата и да се дава път на младите и на новото. Струва ми се, че тези съображения са в сила и за други области на живота.

Не ще съмнение, впрочем, че по-напредналата възраст има своите преимущества. Това са натрупаният опит и знания. Докога, обаче, тези преимущества компенсират неизбежното изоставане и понижение на работоспособността, е много трудно да се каже. Възможностите на отделните хора са много различни, както и областите, в които те работят. Затова нормативното определяне на пределна възраст за учените е несполучливо решение.

Разбира се горното се отнася за доброкачествените изследователи. Масовизирането на науката за съжаление засилва потокът в нея на много негодни кадри. Това се младежи, при които ентусиазмът, смелостта и амбицията да направят нещо хубаво, са заместени от нахалство и кариеризъм, и по-възрастни деятели, които вместо натрупан опит и знания, притежават безогледен стремеж да командват и да ползват облагите от това. За такива трябва метла, която изглежда още не е измислена.

С какво време за научна работа разполагате?

За съжаление времето, с което разполагам за научна работа е крайно недостатъчно. Получава се така, че докато един изследовател е в процес на навлизане в научната работа, той разполага относително с повече време, а когато се оформи и вече е в състояние да реализира натрупания опит, върху него се стоварват безброй странични

задължения, които спъват научното дирене. В този смисъл организацията на нашата работа е крайно несъвършена. Но не само в този смисъл – естественият и прогресивен стремеж за използването на науката във всички области на живота доведе до това, че в управлението на науката се намерват странични, незапознати с нейната специфика хора, които се опитват чрез непремислени и бюрократични прийоми да я насочват. С това, освен излишно губене на много сили и време, развитието на науката се отклонява от нейния естествен и оптимален път, който се определя от условията на работа, нуждите на живота, възможностите и интересите на учения и най-важното от вътрешната логика на развитието на науката, която логика определя обективно и еднозначно посоката и рамките, в които следва да се работи.

Кое е Вашето хоби? Какво ще кажете за връзката между формата и съдържанието?

Аз много обичам музиката и особено Бах. Пленява ме нейната дълбока вътрешна логика и еднозначността на решенията на големите музиканти. Удивително е, че в огромното творчество на Бах някои теми се срещат почти еднакво разработени в най-различни произведения, което доказва, че е намерено абсолютното решение. В други случаи пък темата е развита различно на различни места, но с подчертано хронологически последователно усъвършенстване, подсказващо, че ще се появи, макар и не още намерено, абсолютно решение. Струва ми се, че музиката е именно онова изкуство, което се подчинява най-строго на обективните закони. Нейният особено подчертан абстрактен характер я родее с математиката, макар по-елементарна, но затова пък по-съвършено вътрешно изградена. Може би затова музиката се харесва на много учени. Именно съвършенството на класическата музика прави невъзможно разделянето в нея на формата от съдържанието.

Въпросът за формата и съдържанието в науката се нуждае от уточняване. Начинът на изложение, конструкцията, езикът, качеството на чертежите, а дори понякога прецизността, не са решаващи за една научна работа. Идеята обаче на една работа и средствата – теоретични и експериментални, за нейното разрешаване са в дълбока вътрешна връзка. Съответствието между тях в голяма степен определя крайния резултат. Една сериозна и значителна научна творба има своя собствена красота, определяща се тъкмо в хармонията между идеята и изпълнението. В този смисъл едно научно произведение е сродно на едно произведение на изкуството. Всичко това казвам, за да подчертая дълбокото си убеждение, че всяко постижение на човешката култура, в това число и на науката, трябва да се цени далеч не само по онези непосредствени практически отражения, които то дава в живота. Затова дали и доколко дадено културно постижение ще бъде оползотворено са отговорни условията и организацията в обществото. И няма защо тази отговорност да се стоварва изцяло върху плещите на културните дейци. Рано или късно всяко ново научно откритие, колкото и абстрактно да е то, ще обслужи обществото. Затова на учения, както и на всеки друг културен деятел, следва да се предоставят преди всичко най-големи възможности да се занимава свободно с пряката си творческа дейност. Много вредни са според мен вулгарните спекулации с известните формули за „чистата наука", „наука, откъсната от живота" и за „кулата от слонова кост."[4)] Аз никога няма да забравя как в тази кула у нас и в Съветския съюз до неотдавна бяха настанявани велики генетици. Може и сигурно трябва да се спори за формата и съдържанието, но не бива да се дава път на вулгаризацията и примитивизма.

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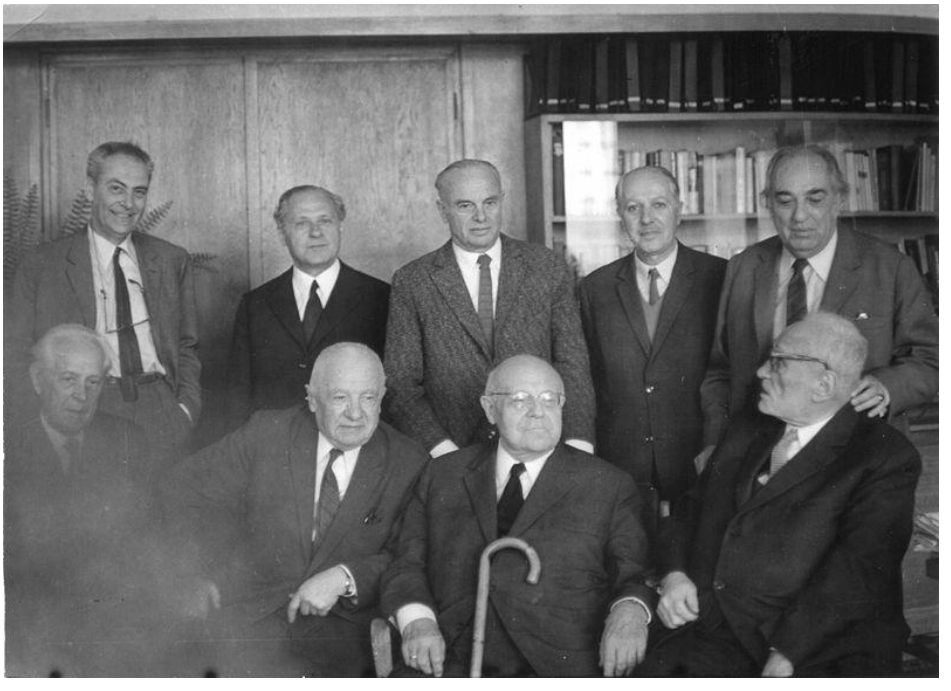

След дълга емиграция проф. Иван Странски (1896-1979) е пак в България (1966) (прави: от ляво на дясно А. Шелудко, Д. Тотоманов, Е. Джаков, С. Христов, Р. Каишев; седнали: от ляво на дясно Ц. Мутафчиев, Г. Наджаков, И. Странски, Д. Иванов)

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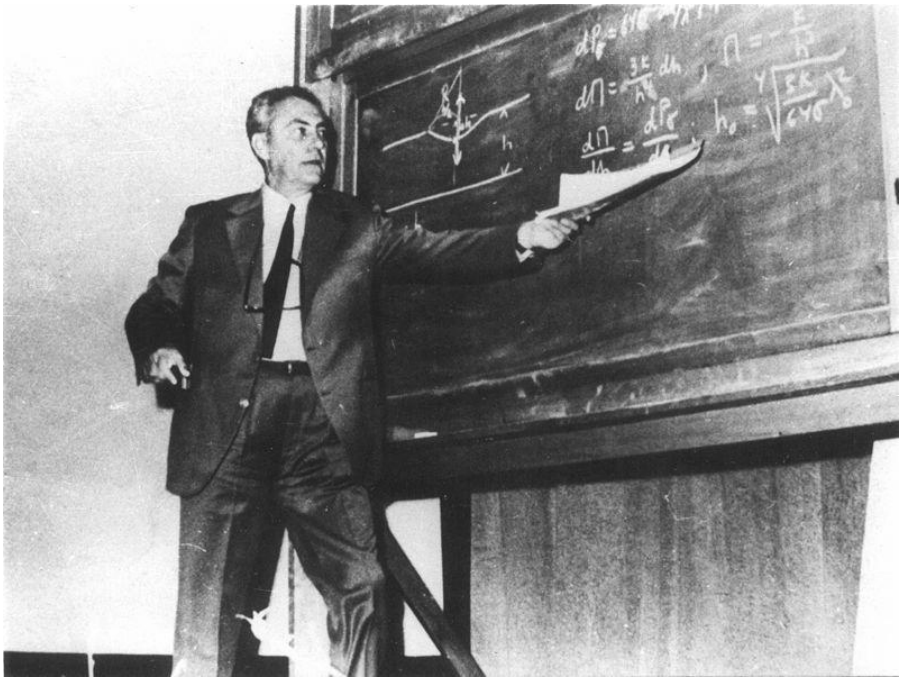

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Тук са изброени няколко непубликувани и недатирани (с едно изключение) ръкописи, от които са намерени по едно или няколко машинописни копия. Върху някои от копията има редакционни поправки и бележки на автора.

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Едно машинописно копие, навярно писано в късната есен на 1985 г.

Шелудко, А. За науката, нейната организация и приложение (ръкопис).

„Спор” на автора (АШ) с въображаем опонент (ША) – 12 машинописни страници.

Шелудко, А. Колоидната химия и научно-техническият прогрес (ръкопис).

Запазени са 4 машинописни копия.

Шелудко, А. Радиоекология (ръкопис).

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Заключение

Катедрата по физикохимия при Софийския университет „Св. Климент Охридски" е създадена в края на 1925 г. от проф. д-р Иван Странски. Корените на прочутата българска физикохимична школа са в това университетско звено. Проф. д-р Ростислав Каишев и проф. дхн Алексей Шелудко са следващите по ред ръководители на Катедрата по физикохимия. В този период се поставиха и корените на българската научна школа по колоидна химия, заслугата за което принадлежи на проф. Шелудко. В следвашите години Катедрата по физикохимия е ръководена от проф. дхн Димо Платиканов, проф. дхн Борян Радоев и проф. дхн Борислав Тошев. Във връзка с 80 годишнината на Катедрата по физикохимия бе създаден Клуб на приятелите на катедрата, който обединява хора от България и чужбина, емоционално или професионално свързани с това учебно-научно звено.[36)] Понастоящем ръководител на Катедрата по физикохимия е проф. дхн Християн Василиев.

Първите ръководители на Катедрата по физикохимия

Днес Катедрата по физикохимия е структурирана в 5 учебно-научни лаборатории: Лаборатория по повърхностни явления и дисперсни системи (проф. дхн Борян Радоев), Лаборатория по биофизикохимия (проф. дхн Иван Панайотов), Лаборатория по физикохимия на твърдото тяло (доц. д-р Стоян Гуцов), Лаборатория по квантова и изчислителна химия (доц. д-р Аля Таджер) и Лаборатория по химическо образование и история и философия на химията (проф. дхн Борислав Тошев). Основно ядро в научната тематика на Катедрата, обаче, продължава да бъде колоидхимичната проблематика и основен научен колоквиум (съвместно с Института по физикохимия на Българската академия на науките) е „Scheludko Colloquium on Collods and Surfaces", ръководен сега от акад. дхн Дочи Ексерова.

Юбилей на акад. Ексерова (2005) – от ляво на дясно (седнали): Д. Ексерова, Н. Рангелова; (прави): М. Недялков, Д. Платиканов, Б.В. Тошев, В. Олчева, Е. Манев, С. Манева, А. Таджер, Х. Василиев

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2. Шелудко, Н. (1967). Д-р Йоаким Исакович Транен (с. 262-265). В.: *Проблеми на историята на медицината в България и българо-руските и българо-съветските медицински връзки. Сборник от статии, посветени на 50-год. на съветската власт*. София.

3. Недатиран ръкопис (машинопис) в 5 страници.

4. С такива формули е прекършен творческия път на много продуктивни българско учени (вж. напр. Чичовска, В. (1995). *Политиката срещу просветната традиция*. София: Унив. изд. „Св. Климент Охридски") (б. авт.).

6. За съавторите на проф. Шелудко в забележки са дадени последните им научни звания и степени заедно с годините на раждане (и на смърт), когато това е известно.

7. Академик Евгени Будевски (1922-2008).

8. Академик Йордан Малиновски (1923-1996).

9. Доц. д-р Мария Тодорова (р. 1924).

10. Академик Ростислав Каишев (1908-2002).

11. Академик Георги Близнаков (1920-2004).

12. н.с. Роза Аврамова Бранц (Поликарова) (р. 1924).

13. Проф. дфн Георги Десимиров (1928-2000)

14. Проф. дхн Костадин Костадинов (Николов) (1931 - 2009).

15. Академик Иван Тодоров (р. 1933).

16. Академик Дочи Русева Ексерова (р. 1935).

17. Проф. дхн Димо Николов Платиканов (р. 1936).

18. Проф. дхн Иван Боянов Иванов (р. 1935).

19. Чл.-кор. дфн Стоил Пешев Стоилов (р. 1935).

20. Stoilov в тази статия.

21. Проф. дхн Емил Деянов Манев (р. 1939).

22. Гл. ас. Николина Рангелова (р. 1935).

23. Проф. дхн Иван Панайотов Иванов (р. 1940).

24. Проф. дхн Борян Пенков Радоев (р. 1941).

25. Н.с. Тодор Коларов (р. 1937).

26. Sheludko в тази статия.

27. Проф. Адолф Фабрикант (1919-1997).

28. Гл.ас. д-р Славка Доксимова Чальовска (1936-1990).

29. Проф дхн Йордан Георгиев Петров (р. 1946).

30. Проф. дхн Михаил Енчев Недялков (р. 1943).

31. Д-р Александър Душков Николов (р. 1948) – сега в САЩ.

32. Проф. дхн Борислав Вълчев Тошев (р. 1943).

33. Д-р Васил Чакъров, сега в САЩ.

34. Освен 4-те български издания, английското и руското издание, книгата на Шелудко е преведена и издадена още на полски и японски езици.

35. Ст.ас. д-р Александър Александров.

36. http://groups.yahoo.com/group/PhysChemSofia

ЛИТЕРАТУРА

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ALEXEI SCHELUDKO (1920-1995): BIBLIOGRAPHY

Abstract. All publications, written by Prof. Dr. Alexei Scheludko (1920-1995), are listed. Prof. Scheludko, f. head of the Department of Physical Chemistry, University of Sofia, and an active member of the Bulgarian Academy of Sciences, is a founder of the scientific school of colloid science in Bulgaria. He is among the most eminent Bulgarian scholars.

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